

# **Supporting Information**

## **for**

### **Copper- and Photocatalytic Radical Relay Enabling Fluoroalkylphosphorothiolation of Alkenes: Modular Synthesis of Fluorine-Containing *S*-Alkyl Phosphorothioates and Phosphorodithioates**

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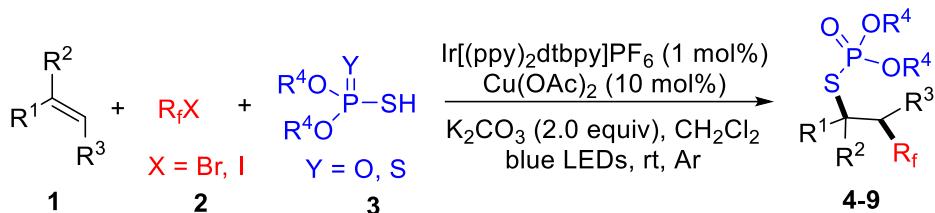
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## General

All commercially available compounds were purchased from Aladdin, Aldrich, Energy chemical or Alfa Aesar and used without further purification, unless stated otherwise. Compounds **1**, **2** and **3** are known compounds. Compounds **1**, which were used for preparing **5f**, **5g**, **9b**, **9d**, **9e**, were prepared according to the known reference: *Org. Lett.* **2020**, *22*, 6299–6303. Bromodifluoroacetamide was prepared according to the known reference: *Org. Lett.* **2021**, *23*, 617–622. Compounds **3** were synthesized according to the known reference: *Org. Lett.* **2021**, *23*, 6729–6734. <sup>1</sup>H NMR was measured on Bruker AVIII 400M. <sup>13</sup>C NMR, <sup>31</sup>P NMR, and <sup>19</sup>F NMR spectra were measured on Bruker AVIII 500M and AVIII 600M spectrometers with CDCl<sub>3</sub> as solvent and tetramethylsilane (TMS) as internal standard. Chemical shifts were reported in units (ppm) by assigning TMS resonance in the <sup>1</sup>H spectrum as 0.00 ppm and CDCl<sub>3</sub> resonance in the <sup>13</sup>C spectrum as 77.23 ppm. All coupling constants (*J* values) were reported in Hertz (Hz). Chemical shifts of common trace <sup>1</sup>H NMR impurities (ppm): H<sub>2</sub>O: 1.56, CHCl<sub>3</sub>: 7.26. HRMS analyses were obtained on a Finnigan-LCQDECA mass spectrometer and a Bruker Daltonics Bio-TOF-Q mass spectrometer by the ESI method, respectively. Column chromatography was performed on silica gel (200-300 mesh). The light-promoted setup apparatus was purchased from Wuhan jiushang Technology Co., Ltd (Model Number: GCH-4, Blue LED bulb (broad spectral range of 460-465 nm, Power density: 6.20 mW/cm<sup>2</sup>). In each case, the light source was placed around 3 cm from the reaction vessel without any filters, and the material of the irradiation vessel is borosilicate glass.

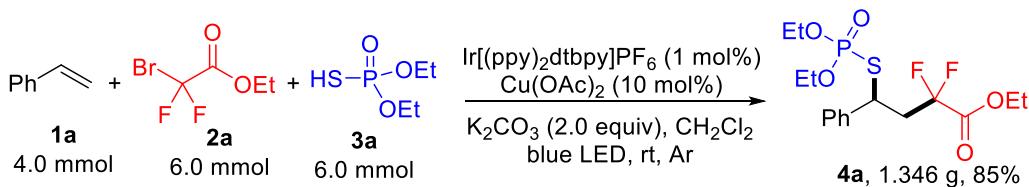
## Experimental procedures

### 1. Copper- and Photocatalytic Fluoroalkylphosphorothiolation of Alkenes



Cu(OAc)<sub>2</sub> (0.03 mmol, 10 mol%), Ir[(ppy)<sub>2</sub>dtbpy]PF<sub>6</sub> (0.003 mmol, 1 mol%), and K<sub>2</sub>CO<sub>3</sub> (0.6 mmol, 2.0 equiv) were placed in a dry Schlenk-tube. tube. The reaction vessel was evacuated and filled with Ar three times. Alkene (0.3 mmol, 1.0 equiv), R<sub>f</sub>X (0.45 mmol, 1.5 equiv) and P(Y)SH compound (0.45 mmol, 1.5 equiv) in DCM (2.5 mL) was then added under Ar and the mixture was stirred under the irradiation of two 3 W blue LEDs strips at room temperature for 12 h. Upon completion, the reaction mixture was concentrated under vacuum. The residue was purified by silica gel column chromatography using a petroleum ether/AcOEt (3:1) as the eluent to give the corresponding products **4-9**.

### 2. Large-Scale Reaction



$\text{Cu}(\text{OAc})_2$  (0.4 mmol, 72.4 mg, 10 mol%),  $\text{Ir}[(\text{ppy})_2\text{dtbpy}]\text{PF}_6$  (0.04 mmol, 34.9 mg, 1 mol%), and  $\text{K}_2\text{CO}_3$  (8.0 mmol, 1.104 g, 2.0 equiv) were placed in a dry Schlenk-tube. tube. The reaction vessel was evacuated and filled with Ar three times. Alkene (4.0 mmol, 416.0 mg, 1.0 equiv),  $\text{BrCF}_2\text{COOEt}$  (6.0 mmol, 1.212 g, 1.5 equiv) and  $(\text{EtO})_2\text{P}(\text{O})\text{SH}$  (6.0 mmol, 1.020 g, 1.5 equiv) in DCM (25 mL) was then added and the mixture was stirred under the irradiation of a 18 W blue LED at room temperature for 24 h. Upon completion, the resulting mixture was extracted with  $\text{CH}_2\text{Cl}_2$  and dried over anhydrous  $\text{Na}_2\text{SO}_4$ . After the solvent was removed by evaporation under reduced pressure, the residue was purified by silica gel column chromatography using a petroleum ether/AcOEt (3:1) as the eluent to give the corresponding products **4a** (1.346 g, 85%).

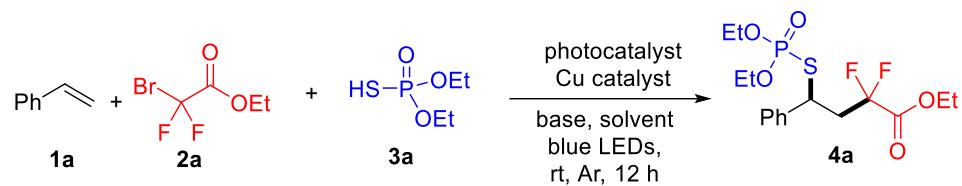
### 3. Experimental setup



Figure S1. The setup apparatus described in this work



Figure S2. The setup apparatus for large-scale reaction

**Table S1. Optimization of the Reaction Conditions<sup>a</sup>**

entry	photocatalyst	Cu catalyst	base	solvent	yield (%) <sup>b</sup>
1	Ir(ppy) <sub>3</sub>	Cu(OAc) <sub>2</sub>	K <sub>2</sub> CO <sub>3</sub>	DCM	64
2	Ru(bpy) <sub>3</sub> Cl <sub>2</sub>	Cu(OAc) <sub>2</sub>	K <sub>2</sub> CO <sub>3</sub>	DCM	trace
3	Eosin Y	Cu(OAc) <sub>2</sub>	K <sub>2</sub> CO <sub>3</sub>	DCM	trace
4	4CzIPN	Cu(OAc) <sub>2</sub>	K <sub>2</sub> CO <sub>3</sub>	DCM	19
<b>5</b>	<b>Ir[(ppy)<sub>2</sub>dtbpy]PF<sub>6</sub></b>	<b>Cu(OAc)<sub>2</sub></b>	<b>K<sub>2</sub>CO<sub>3</sub></b>	<b>DCM</b>	<b>92</b>
6	-	Cu(OAc) <sub>2</sub>	K <sub>2</sub> CO <sub>3</sub>	DCM	trace
7	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	-	K <sub>2</sub> CO <sub>3</sub>	DCM	19
8	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	Cu(OTf) <sub>2</sub>	K <sub>2</sub> CO <sub>3</sub>	DCM	90
9	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	CuI	K <sub>2</sub> CO <sub>3</sub>	DCM	78
10	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	CuBr	K <sub>2</sub> CO <sub>3</sub>	DCM	82
11	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	CuSO <sub>4</sub>	K <sub>2</sub> CO <sub>3</sub>	DCM	57
12	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	CuCl	K <sub>2</sub> CO <sub>3</sub>	DCM	83
13	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	CuBr <sub>2</sub>	K <sub>2</sub> CO <sub>3</sub>	DCM	67
14	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	Cu	K <sub>2</sub> CO <sub>3</sub>	DCM	39
15	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	Cu(OAc) <sub>2</sub>	-	DCM	trace
16	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	Cu(OAc) <sub>2</sub>	t-BuONa	DCM	73
17	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	Cu(OAc) <sub>2</sub>	Cs <sub>2</sub> CO <sub>3</sub>	DCM	25
18	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	Cu(OAc) <sub>2</sub>	Et <sub>3</sub> N	DCM	68
19	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	Cu(OAc) <sub>2</sub>	2,6-lutidine	DCM	36
20	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	Cu(OAc) <sub>2</sub>	K <sub>2</sub> CO <sub>3</sub>	EtOH	56
21	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	Cu(OAc) <sub>2</sub>	K <sub>2</sub> CO <sub>3</sub>	MeCN	20
22	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	Cu(OAc) <sub>2</sub>	K <sub>2</sub> CO <sub>3</sub>	1,4-dioxane	30
23	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	Cu(OAc) <sub>2</sub>	K <sub>2</sub> CO <sub>3</sub>	toluene	46
24	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	Cu(OAc) <sub>2</sub>	K <sub>2</sub> CO <sub>3</sub>	DMSO	trace
25 <sup>c</sup>	Ir[(ppy) <sub>2</sub> dtbpy]PF <sub>6</sub>	Cu(OAc) <sub>2</sub>	K <sub>2</sub> CO <sub>3</sub>	DCM	0

<sup>a</sup>Reaction conditions: **1a** (0.3 mmol), **2a** (0.45 mmol), **3a** (0.45 mmol), photocatalyst (1 mol%), Cu catalyst (10 mol%), and base (0.6 mmol) were dissolved in solvent (2.5 mL) and irradiated by two 3 W blue LEDs strips for 12 h at room temperature under Ar; <sup>b</sup>Isolated yield; <sup>c</sup>Under dark.

**Table S2. Investigation of the Four-component Reaction<sup>a</sup>**

photocatalyst  
 $\text{Cu}(\text{OAc})_2$   
 base,  $\text{CH}_2\text{Cl}_2$ ,  
 blue LEDs,  
 rt, Ar, 12 h

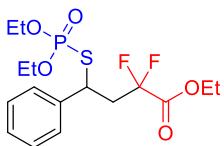
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entry	photocatalyst	base	yield (%) <sup>b</sup>
1	$\text{Ir}(\text{ppy})_3$	$\text{Et}_3\text{N}$	44
2	$\text{Ir}(\text{ppy})_3$	$t\text{-BuONa}$	42
3	$\text{Ir}[(\text{ppy})_2\text{dtbpy}]\text{PF}_6$	$\text{K}_2\text{CO}_3$	trace
4	$\text{Ir}[(\text{ppy})_2\text{dtbpy}]\text{PF}_6$	$\text{Et}_3\text{N}$	43
5	$\text{Ir}[(\text{ppy})_2\text{dtbpy}]\text{PF}_6$	$t\text{-BuONa}$	65

<sup>a</sup>Reaction conditions:  $\text{S}_8$  (19.2 mg, 0.60 mmol),  $\text{P}(\text{O})\text{H}$  (0.6 mmol), photocatalyst (1 mol%),  $\text{Cu}(\text{OAc})_2$  (10 mol%), and base (0.6 mmol) were dissolved in  $\text{CH}_2\text{Cl}_2$  (2.5 mL) and stirred at rt for 20 min; **1a** (0.3 mmol) and **2a** (0.6 mmol) were then added and the reaction mixture was irradiated by two 3 W blue LEDs strips for 12 h at room temperature under Ar; <sup>b</sup>Isolated yield.

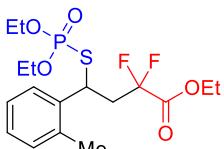
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Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-4-phenylbutanoate (**4a**)



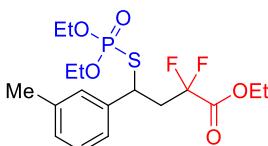
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 109.3 mg, 92%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.37-7.26 (m, 5H), 4.54-4.47 (m, 1H), 4.10-3.96 (m, 5H), 3.83-3.73 (m, 1H), 2.98-2.82 (m, 2H), 1.27 (t,  $J$  = 7.1 Hz, 3H), 1.25 (t,  $J$  = 7.1 Hz, 3H), 1.18 (t,  $J$  = 7.1 Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.4 (t,  $J$  = 32.2 Hz), 140.6 (d,  $J$  = 3.9 Hz), 128.8, 128.4, 127.9, 114.5 (t,  $J$  = 252.6 Hz), 63.9 (d,  $J$  = 5.9 Hz), 63.8 (d,  $J$  = 5.6 Hz), 44.1-43.9 (m), 42.5 (td,  $J$  = 23.8, 8.0 Hz), 16.04 (d,  $J$  = 7.6 Hz), 15.94 (d,  $J$  = 7.6 Hz), 13.9.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  23.95.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.52 (d,  $J$  = 265.6 Hz), -105.36 (d,  $J$  = 265.5 Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{16}\text{H}_{24}\text{F}_2\text{O}_5\text{PS}^+$ : 397.1045, found: 397.1043.

Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-4-(o-tolyl)butanoate (**4b**)



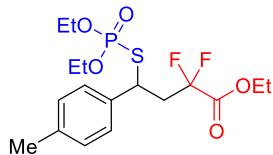
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 107.0 mg, 87%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.34 (d,  $J$  = 7.4 Hz, 1H), 7.18-7.14 (m, 1H), 7.12-7.08 (m, 2H), 4.82-4.74 (m, 1H), 4.09-3.97 (m, 3H), 3.97-3.88 (m, 2H), 3.82 -3.69 (m, 1H), 2.96-2.84 (m, 2H), 2.40 (s, 3H), 1.26 (t,  $J$  = 7.1 Hz, 3H), 1.19 (t,  $J$  = 7.2 Hz, 3H), 1.14 (t,  $J$  = 7.1 Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.31 (t,  $J$  = 32.2 Hz), 138.36, 135.93, 130.75, 128.08, 127.65, 126.54, 114.5 (t,  $J$  = 252.6 Hz), 63.9 (d,  $J$  = 5.9 Hz), 63.8 (d,  $J$  = 5.8 Hz), 63.1, 42.7-42.1 (m), 40.0-39.8 (m), 19.3, 16.0 (d,  $J$  = 7.5 Hz), 15.9 (d,  $J$  = 7.5 Hz), 13.8.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  24.35.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.18 (d,  $J$  = 264.4 Hz), -105.73 (d,  $J$  = 263.6 Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{17}\text{H}_{26}\text{F}_2\text{O}_5\text{PS}^+$ : 411.1201, found: 411.1197.

Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-4-(m-tolyl)butanoate (**4c**)



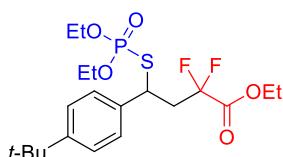
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 105.8 mg, 86%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.21 (t,  $J$  = 7.5 Hz, 1H), 7.16-7.12 (m, 2H), 7.08 (d,  $J$  = 7.3 Hz, 1H), 4.50-4.43 (m, 1H), 4.1-3.95 (m, 5H), 3.85-3.74 (m, 1H), 3.00-2.80 (m, 2H), 2.34 (s, 3H), 1.27 (t,  $J$  = 7.2 Hz, 3H), 1.24 (t,  $J$  = 7.2 Hz, 3H), 1.19 (t,  $J$  = 7.1 Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.4 (t,  $J$  = 32.3 Hz), 140.4 (d,  $J$  = 4.1 Hz), 138.4, 129.0, 128.7 128.4, 124.9, 114.5 (t,  $J$  = 252.6 Hz), 63.8 (d,  $J$  = 5.9 Hz), 63.7 (d,  $J$  = 5.6 Hz), 63.1, 44.0-43.9 (m), 42.5 (td,  $J$  = 23.8, 7.5 Hz), 21.4, 16.0 (d,  $J$  = 7.5 Hz), 15.9 (d,  $J$  = 7.6 Hz), 13.8.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  24.08.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.55 (d,  $J$  = 265.4 Hz), -105.29 (d,  $J$  = 265.4 Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{17}\text{H}_{26}\text{F}_2\text{O}_5\text{PS}^+$ : 411.1201, found: 411.1205.

Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-4-(*p*-tolyl)butanoate (**4d**)



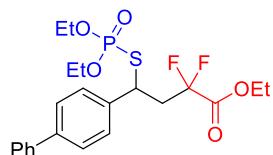
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 86.1 mg, 70%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.22-7.18 (m, 2H), 7.12-7.08 (m, 2H), 4.49-4.42 (m, 1H), 4.07-3.93 (m, 5H), 3.83-3.73 (m, 1H), 2.96-2.81 (m, 2H), 2.30 (s, 3H), 1.27-1.23 (t, J = 7.2 Hz, 3H), 1.21 (t, J = 7.2 Hz, 3H), 1.17 (t, J = 7.1 Hz, 3H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>) δ 163.4 (t, J = 32.3 Hz), 138.2, 137.4 (d, J = 4.3 Hz), 129.4, 127.7, 114.4 (t, J = 252.6 Hz), 63.9 (d, J = 5.9 Hz), 63.8 (d, J = 5.6 Hz), 63.1, 43.89-43.8 (m), 42.5 (td, J = 23.7, 7.5 Hz), 21.22, 16.0 (d, J = 7.6 Hz), 15.9 (d, J = 7.6 Hz), 13.83. <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>) δ 24.22. <sup>19</sup>F NMR (471 MHz, CDCl<sub>3</sub>) δ -102.53 (d, J = 265.3 Hz), -105.33 (d, J = 265.3 Hz). HRMS: [M+Na]<sup>+</sup> m/z calcd for C<sub>17</sub>H<sub>25</sub>F<sub>2</sub>NaO<sub>5</sub>PS<sup>+</sup>: 433.1021, found: 433.1028.

Ethyl 4-(4-(*tert*-butyl)phenyl)-4-((diethoxyphosphoryl)thio)-2,2-difluorobutanoate (**4e**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 122.0 mg, 90%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.36-7.32 (m, 2H), 7.29-7.24 (m, 2H), 4.52-4.42 (m, 1H), 4.08-3.88 (m, 5H), 3.82-3.70 (m, 1H), 2.96-2.86 (m, 2H), 1.29 (s, 9H), 1.25 (t, J = 7.1 Hz, 3H), 1.20 (t, J = 7.1 Hz, 3H), 1.15 (t, J = 7.1 Hz, 3H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>) δ 163.38 (t, J = 32.2 Hz), 151.4, 137.3 (d, J = 3.9 Hz), 127.7, 125.7, 114.50 (t, J = 252.6 Hz), 63.8 (d, J = 5.8 Hz), 63.7 (d, J = 5.5 Hz), 63.1, 43.8-43.7 (m), 42.4 (td, J = 24.0, 8.1 Hz), 34.7, 31.4, 16.0 (d, J = 7.6 Hz), 15.9 (d, J = 7.7 Hz), 13.9. <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>) δ 24.09. <sup>19</sup>F NMR (471 MHz, CDCl<sub>3</sub>) δ -101.91 (d, J = 265.2 Hz), -105.83 (d, J = 265.3 Hz). HRMS: [M+H]<sup>+</sup> m/z calcd for C<sub>20</sub>H<sub>32</sub>F<sub>2</sub>O<sub>5</sub>PS<sup>+</sup>: 453.1671, found: 453.1672.

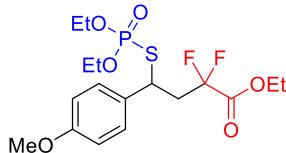
Ethyl 4-([1,1'-biphenyl]-4-yl)-4-((diethoxyphosphoryl)thio)-2,2-difluorobutanoate (**4f**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 124.6 mg, 88%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.57-7.53 (m, 4H), 7.45-7.41 (m, 4H), 7.36-7.33 (m, 1H), 4.60-4.54 (m, 1H), 4.12-3.97 (m, 5H), 3.88-3.78 (m, 1H), 3.00-2.86 (m, 2H), 1.26 (t, J = 7.1 Hz, 3H), 1.22 (t, J = 7.1 Hz, 3H), 1.18 (t, J = 7.1 Hz, 3H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>) δ 163.35 (t, J = 32.3 Hz), 141.2, 140.4, 139.5 (d, J = 3.8 Hz), 129.0, 128.3, 127.7, 127.4, 127.1, 114.5 (t, J = 252.1 Hz), 63.9 (d, J = 5.9 Hz), 63.8 (d, J = 5.6 Hz), 63.2, 43.8-43.6 (m), 42.3 (td, J = 23.8, 7.9 Hz), 16.0 (d, J = 7.5 Hz), 15.9 (d, J = 7.6 Hz), 13.8. <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>) δ 23.91. <sup>19</sup>F NMR (471 MHz, CDCl<sub>3</sub>) δ -102.40 (d, J = 265.5 Hz), -105.19 (d, J = 265.5 Hz). HRMS: [M+Na]<sup>+</sup>

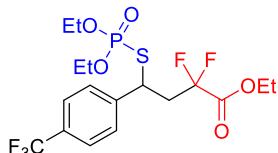
*m/z* calcd for C<sub>22</sub>H<sub>27</sub>F<sub>2</sub>NaO<sub>5</sub>PS<sup>+</sup>: 495.1177, found: 495.1170.

Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-4-(4-methoxyphenyl)butanoate (**4g**)



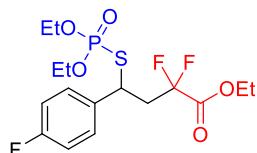
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 113.7 mg, 89%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.29-7.25 (m, 2H), 6.87-6.83 (m, 2H), 4.53-4.46 (m, 1H), 4.13-3.95 (m, 5H), 3.89-3.80 (m, 1H), 3.79 (s, 3H), 2.96-2.85 (m, 2H), 1.27 (t, J = 7.1 Hz, 3H), 1.24 (t, J = 7.1 Hz, 3H), 1.22 (t, J = 7.1 Hz, 3H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>) δ 163.4 (t, J = 32.3 Hz), 159.5, 132.3 (d, J = 4.3 Hz), 129.1, 114.5 (t, J = 252.6 Hz), 114.04, 63.8 (d, J = 5.9 Hz), 63.7 (d, J = 5.7 Hz), 63.11, 55.4, 43.7-43.6 (m), 42.6 (td, J = 23.7, 7.6 Hz), 16.0 (d, J = 7.9 Hz), 15.9 (d, J = 7.8 Hz), 13.8. <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>) δ 24.18. <sup>19</sup>F NMR (471 MHz, CDCl<sub>3</sub>) δ -102.38 (d, J = 265.2 Hz), -105.53 (d, J = 265.3 Hz). HRMS: [M+H]<sup>+</sup> *m/z* calcd for C<sub>17</sub>H<sub>26</sub>F<sub>2</sub>O<sub>6</sub>PS<sup>+</sup>: 427.1150, found: 427.1145.

Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-4-(4-(trifluoromethyl)phenyl)butanoate (**4h**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 108.6 mg, 78%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.59-7.55 (m, 2H), 7.50-7.45 (m, 2H), 4.60-4.53 (m, 1H), 4.09-4.01 (m, 3H), 4.00-3.90 (m, 2H), 3.87-3.76 (m, 1H), 2.95-2.81 (m, 2H), 1.23 (t, J = 7.1 Hz, 3H), 1.20 (t, J = 7.1 Hz, 3H), 1.16 (t, J = 7.1 Hz, 3H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>) δ 163.3 (t, J = 32.1 Hz), 144.9, 130.5 (q, J = 32.6 Hz), 128.4, 125.7 (q, J = 3.6 Hz), 124.0 (q, J = 272.1 Hz), 114.3 (t, J = 252.8 Hz), 64.1 (d, J = 4.9 Hz), 64.06 (d, J = 5.6 Hz), 63.3, 43.43-43.27 (m), 42.0 (td, J = 23.7, 8.5 Hz), 15.9 (d, J = 6.4 Hz), 15.8 (d, J = 7.0 Hz). 13.8. <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>) δ 23.23. <sup>19</sup>F NMR (471 MHz, CDCl<sub>3</sub>) δ -62.82 (s), -103.34 (d, J = 266.4 Hz), -104.67 (d, J = 266.4 Hz). HRMS: [M+H]<sup>+</sup> *m/z* calcd for C<sub>17</sub>H<sub>23</sub>F<sub>5</sub>O<sub>5</sub>PS<sup>+</sup>: 465.0918, found: 465.0914.

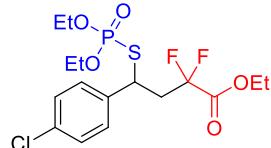
Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-4-(4-fluorophenyl)butanoate (**4i**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 62.1 mg, 50%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.33-7.30 (m, 2H), 7.01-6.97 (m, 2H), 4.54-4.47 (m, 1H), 4.10-3.91 (m, 5H), 3.87-3.76 (m, 1H), 2.93-2.78 (m, 2H), 1.26-1.21 (m, 6H), 1.19 (t, J = 7.1 Hz, 3H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>) δ 163.3 (t, J = 31.9 Hz), 162.5 (d, J = 247.8 Hz), 136.6-136.5 (m), 129.7 (d, J = 8.1 Hz), 115.7 (d, J = 21.7 Hz), 114.4 (t, J = 252.6 Hz), 63.93 (d, J = 5.8 Hz), 63.89 (d, J = 5.7 Hz), 63.25, 43.4-43.2 (m), 42.4 (td, J = 23.5, 7.9 Hz), 16.0 (d, J = 5.2 Hz), 15.9 (d, J = 5.3 Hz), 13.9. <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>) δ 23.62. <sup>19</sup>F NMR (471 MHz, CDCl<sub>3</sub>)

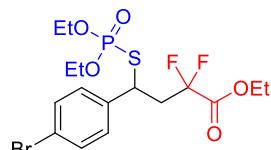
$\delta$  -102.97 (d,  $J$  = 265.8 Hz), -105.10 (d,  $J$  = 265.9 Hz), -113.43. HRMS: [M+H]<sup>+</sup>  $m/z$  calcd for C<sub>16</sub>H<sub>23</sub>F<sub>3</sub>O<sub>5</sub>PS<sup>+</sup>: 415.0950, found: 415.0955.

Ethyl 4-(4-chlorophenyl)-4-((diethoxyphosphoryl)thio)-2,2-difluorobutanoate (**4j**)



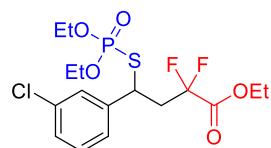
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 83.8 mg, 65%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.33-7.30 (m, 4H), 4.55-4.49 (m, 1H), 4.12-3.95 (m, 5H), 3.90-3.80 (m, 1H), 2.99-2.78 (m, 2H), 1.30-1.23 (m, 6H), 1.22 (t,  $J$  = 7.1 Hz, 3H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>)  $\delta$  163.3 (t,  $J$  = 32.1 Hz), 139.2 (d,  $J$  = 3.8 Hz), 134.1, 129.3, 128.9, 114.3 (t,  $J$  = 252.6 Hz), 64.02 (d,  $J$  = 6.3 Hz), 63.98 (d,  $J$  = 6.1 Hz), 43.4-43.2 (m), 42.2 (td,  $J$  = 23.7, 8.2 Hz), 16.0 (d,  $J$  = 6.5 Hz), 15.9 (d,  $J$  = 7.0 Hz), 13.9. <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>)  $\delta$  23.58. <sup>19</sup>F NMR (471 MHz, CDCl<sub>3</sub>)  $\delta$  -103.09 (d,  $J$  = 266.1 Hz), -104.87 (d,  $J$  = 266.1 Hz). HRMS: [M+H]<sup>+</sup>  $m/z$  calcd for C<sub>16</sub>H<sub>23</sub>ClF<sub>2</sub>O<sub>5</sub>PS<sup>+</sup>: 431.0655, found: 431.0659.

Ethyl 4-(4-bromophenyl)-4-((diethoxyphosphoryl)thio)-2,2-difluorobutanoate (**4k**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 106.6 mg, 75%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.43-7.38 (m, 2H), 7.22-7.16 (m, 2H), 4.49-4.42 (m, 1H), 4.07-3.90 (m, 5H), 3.86-3.76 (m, 1H), 2.94-2.73 (m, 2H), 1.24-1.18 (m, 6H), 1.15 (t,  $J$  = 7.1 Hz, 3H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>)  $\delta$  163.30 (t,  $J$  = 32.1 Hz), 114.34 (t,  $J$  = 252.6 Hz), 63.96 (d,  $J$  = 6.2 Hz), 63.92 (d,  $J$  = 6.0 Hz), 43.33 (dd,  $J$  = 8.7, 3.9 Hz), 42.15 (td,  $J$  = 23.6, 8.1 Hz), 15.98 (d,  $J$  = 6.7 Hz), 15.94 (d,  $J$  = 6.9 Hz). <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>)  $\delta$  23.46. <sup>19</sup>F NMR (471 MHz, CDCl<sub>3</sub>)  $\delta$  -103.07 (d,  $J$  = 266.1 Hz), -104.83 (d,  $J$  = 266.1 Hz). HRMS: [M+H]<sup>+</sup>  $m/z$  calcd for C<sub>16</sub>H<sub>23</sub>BrF<sub>2</sub>O<sub>5</sub>PS<sup>+</sup>: 475.0150, found: 475.0144.

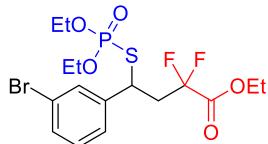
Ethyl 4-(3-chlorophenyl)-4-((diethoxyphosphoryl)thio)-2,2-difluorobutanoate (**4l**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 83.8 mg, 65%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.37-7.35 (m, 1H), 7.29-7.23 (m, 3H), 4.53-4.46 (m, 1H), 4.15-3.95 (m, 5H), 3.89-3.79 (m, 1H), 2.98-2.78 (m, 2H), 1.30-1.25 (m, 6H), 1.21 (t,  $J$  = 7.1 Hz, 3H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>)  $\delta$  163.3 (t,  $J$  = 32.2 Hz), 142.8 (d,  $J$  = 3.6 Hz), 134.6, 130.2, 128.5, 128.0, 126.2, 114.3 (t,  $J$  = 252.5 Hz), 64.1 (d,  $J$  = 6.0 Hz), 64.0 (d,  $J$  = 5.7 Hz), 63.4, 43.4 (dd,  $J$  = 8.9, 4.0 Hz), 42.2 (td,  $J$  = 23.8, 8.3 Hz), 16.0 (d,  $J$  = 7.5 Hz), 15.96 (d,  $J$  = 7.5 Hz), 13.9. <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>)  $\delta$  23.40. <sup>19</sup>F NMR (471 MHz, CDCl<sub>3</sub>)  $\delta$  -103.01 (d,  $J$  = 266.3 Hz), -104.89 (d,  $J$  = 266.4 Hz). HRMS: [M+H]<sup>+</sup>  $m/z$  calcd for C<sub>16</sub>H<sub>23</sub>ClF<sub>2</sub>O<sub>5</sub>PS<sup>+</sup>: 431.0655, found:

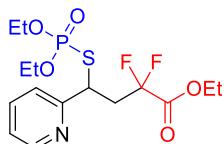
431.0662.

Ethyl 4-(3-bromophenyl)-4-((diethoxyphosphoryl)thio)-2,2-difluorobutanoate (**4m**)



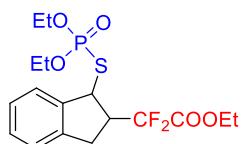
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 108.1 mg, 76%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.53-7.51 (m, 1H), 7.44-7.40 (m, 1H), 7.32-7.28 (m, 1H), 7.21 (t, J = 7.8 Hz, 1H), 4.51-4.45 (m, 1H), 4.14-3.94 (m, 5H), 3.90-3.79 (m, 1H), 2.99-2.77 (m, 2H), 1.31-1.25 (m, 6H), 1.21 (t, J = 7.1 Hz, 3H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>) δ 163.2 (t, J = 32.1 Hz), 142.9 (d, J = 3.4 Hz), 131.4, 130.8, 130.4, 126.7, 122.6, 114.3 (t, J = 252.5 Hz), 64.2 (d, J = 6.1 Hz), 64.1 (d, J = 5.8 Hz), 63.4, 43.3 (dd, J = 8.5, 4.0 Hz), 16.0 (d, J = 7.5 Hz), 15.9 (d, J = 7.3 Hz), 13.9. <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>) δ 24.80. <sup>19</sup>F NMR (471 MHz, CDCl<sub>3</sub>) δ -103.26 (d, J = 264.3 Hz), -104.90 (d, J = 264.3 Hz). HRMS: [M+H]<sup>+</sup> m/z calcd for C<sub>16</sub>H<sub>23</sub>BrF<sub>2</sub>O<sub>5</sub>PS<sup>+</sup>: 475.0150, found: 475.0157.

Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-4-(pyridin-2-yl)butanoate (**4n**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 65.5 mg, 55%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 8.56 (d, J = 4.5 Hz, 1H), 7.66-7.59 (m, 1H), 7.31 (d, J = 7.8 Hz, 1H), 7.18 (dd, J = 7.5, 4.9 Hz, 1H), 4.68-4.59 (m, 1H), 4.16-4.04 (m, 3H), 4.03-3.86 (m, 3H), 3.28-3.14 (m, 1H), 2.95-2.82 (m, 1H), 1.27-1.20 (m, 9H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>) δ 163.5 (t, J = 32.3 Hz), 159.1 (d, J = 4.1 Hz), 150.0, 137.0, 123.2, 123.1, 114.7 (t, J = 252.0 Hz), 64.0 (d, J = 6.0 Hz), 63.2, 44.7 (dd, J = 7.4, 3.9 Hz), 40.8 (td, J = 23.3, 6.9 Hz), 16.1 (d, J = 3.7 Hz), 16.0 (d, J = 3.9 Hz), 14.0. <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>) δ 24.37. <sup>19</sup>F NMR (471 MHz, CDCl<sub>3</sub>) δ -103.95 (d, J = 263.1 Hz), -104.84 (d, J = 263.1 Hz). HRMS: [M+H]<sup>+</sup> m/z calcd for C<sub>15</sub>H<sub>23</sub>F<sub>2</sub>NO<sub>5</sub>PS<sup>+</sup>: 398.0997, found: 398.0996.

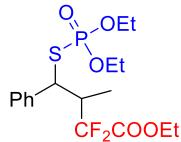
Ethyl 2-(1-((diethoxyphosphoryl)thio)-2,3-dihydro-1H-inden-2-yl)-2,2-difluoroacetate (**4o**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 89.4 mg, 73%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.46-7.44 (m, 1H), 7.24-7.19 (m, 2H), 7.18-7.15 (m, 1H), 4.98 (dd, J = 15.4, 3.7 Hz, 1H), 4.23-4.06 (m, 6H), 3.54-3.42 (m, 1H), 3.38-3.31 (m, 1H), 3.09-3.04 (m, 1H), 1.34 (t, J = 7.1 Hz, 3H), 1.33 (t, J = 7.1 Hz, 3H), 1.23 (t, J = 7.1 Hz, 3H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>) δ 163.4 (t, J = 32.4 Hz), 141.3 (d, J = 5.7 Hz), 140.5, 128.8, 127.6, 125.5, 124.6, 116.0 (t, J = 253.8 Hz), 64.04 (d, J = 6.7 Hz), 63.99 (d, J = 7.4 Hz), 63.2, 51.61 (td, J = 22.7, 3.8 Hz), 49.0-48.9 (m), 31.4-31.3 (m), 16.1 (d, J = 7.2 Hz), 13.9. <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>)

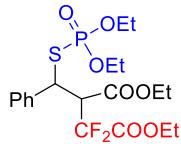
$\delta$  24.71.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -109.33 (d,  $J = 255.7$  Hz), -111.74 (d,  $J = 255.7$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{17}\text{H}_{24}\text{F}_2\text{O}_5\text{PS}^+$ : 409.1045, found: 409.1039.

Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-3-methyl-4-phenylbutanoate (**4p**, dr = 9.8:1)



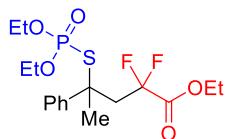
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 70.1 mg, 57%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.42-7.39 (m, 2H), 7.34-7.30 (m, 2H), 7.28-7.24 (m, 1H), 4.55 (dd,  $J = 13.1, 6.2$  Hz, 1H), 4.14-4.07 (m, 2H), 4.04-3.85 (m, 3H), 3.69-3.59 (m, 1H), 2.89-2.78 (m, 1H), 1.35-1.26 (m, 6H), 1.21 (t,  $J = 7.1$  Hz, 3H), 1.06 (t,  $J = 7.1$  Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.6 (t,  $J = 32.5$  Hz), 141.2, 128.9, 128.7, 128.4, 127.9, 116.3 (t,  $J = 253.8$  Hz), 63.6 (d,  $J = 5.4$  Hz), 63.1, 50.3-50.2 (m), 44.4 (td,  $J = 21.6, 8.9$  Hz), 15.9 (d,  $J = 7.7$  Hz), 15.7 (d,  $J = 7.8$  Hz), 14.0, 10.6-10.4 (m).  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  25.08.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -107.38 (d,  $J = 262.3$  Hz), -111.37 (d,  $J = 262.3$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{17}\text{H}_{26}\text{F}_2\text{O}_5\text{PS}^+$ : 411.1201, found: 411.1207.

Diethyl 3-((diethoxyphosphoryl)thio)(phenyl)methyl)-2,2-difluorosuccinate (**4q**, dr = 10:1)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 40.7 mg, 29%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.45-7.41 (m, 2H), 7.34-7.27 (m, 3H), 4.76 (dd,  $J = 12.2, 11.1$  Hz, 1H), 4.36-4.25 (m, 2H), 4.04-3.77 (m, 6H), 3.48-3.37 (m, 1H), 1.36 (t,  $J = 7.1$  Hz, 3H), 1.28 (td,  $J = 7.1, 0.8$  Hz, 3H), 1.18 (t,  $J = 7.2$  Hz, 3H), 1.00 (td,  $J = 7.1, 0.6$  Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  166.8 (dd,  $J = 2.7, 1.4$  Hz), 162.0 (t,  $J = 31.3$  Hz), 138.5, 129.4, 128.6, 128.5, 113.3 (dd,  $J = 262.5, 253.0$  Hz), 63.8 (d,  $J = 5.1$  Hz), 63.5 (d,  $J = 5.0$  Hz), 63.4, 62.4, 56.2 (td,  $J = 21.8, 11.0$  Hz), 47.3-47.1 (m), 16.0 (d,  $J = 7.9$  Hz), 15.7 (d,  $J = 7.9$  Hz), 14.2, 13.8.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  23.31.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -101.25 (d,  $J = 273.2$  Hz), -111.81 (d,  $J = 273.3$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{19}\text{H}_{28}\text{F}_2\text{O}_7\text{PS}^+$ : 469.1256, found: 469.1260.

Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-4-phenylpentanoate (**4r**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 97.2 mg, 79%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.57-7.53 (m, 2H), 7.38-7.32 (m, 2H), 7.29-7.25 (m, 1H), 4.14-3.75 (m, 6H), 3.36-3.28 (m, 2H), 2.22 (s, 3H), 1.27 (t,  $J = 7.1$  Hz, 3H), 1.24 (t,  $J = 7.1$  Hz, 3H), 1.19 (t,  $J = 7.1$  Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.6 (t,  $J = 32.2$  Hz), 142.0 (d,  $J = 7.8$  Hz), 128.3, 128.0, 127.1, 114.8 (dd,  $J = 255.0, 251.1$  Hz), 63.9 (d,  $J = 6.3$  Hz), 62.95, 53.9-53.8 (m), 46.7 (td,  $J = 24.0, 5.2$  Hz), 26.7, 16.1 (d,  $J = 6.1$  Hz), 16.0 (d,  $J = 7.1$  Hz),

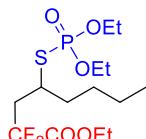
13.7.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  21.81.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -96.46 (d,  $J = 262.3$  Hz), -102.29 (d,  $J = 262.3$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{17}\text{H}_{26}\text{F}_2\text{O}_5\text{PS}^+$ : 411.1201, found: 411.1209.

#### Ethyl 2-((diethoxyphosphoryl)thio)-2-phenylcyclohexyl)-2,2-difluoroacetate (**4s**)



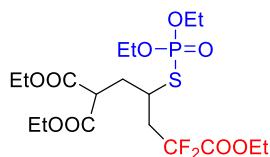
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 54.0 mg, 40%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.65-7.55 (m, 2H), 7.32-7.27 (m, 2H), 7.25-7.20 (m, 1H), 4.00-3.84 (m, 2H), 3.80-3.56 (m, 4H), 3.30-3.18 (m, 1H), 2.75-2.55 (m, 2H), 2.25-2.07 (m, 3H), 1.95-1.85 (m, 1H), 1.75-1.65 (m, 1H), 1.62-1.52 (m, 1H), 1.16 (t,  $J = 7.1$  Hz, 3H), 1.14 (t,  $J = 7.1$  Hz, 3H), 1.09 (t,  $J = 7.1$  Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.7 (t,  $J = 32.4$  Hz), 142.8, 128.9, 127.7, 127.6, 116.6 (dd,  $J = 255.0, 251.1$  Hz), 63.6 (d,  $J = 6.3$  Hz), 63.5 (d,  $J = 7.1$  Hz), 62.9, 61.2-61.0 (m), 47.6-47.2 (m), 30.6 (d,  $J = 5.3$  Hz), 22.5 (d,  $J = 9.0$  Hz), 21.9, 20.9, 16.2 (d,  $J = 7.0$  Hz), 16.0 (d,  $J = 7.6$  Hz), 13.7.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  22.0.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -95.43 (d,  $J = 266.6$  Hz), -103.04 (d,  $J = 266.6$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{20}\text{H}_{30}\text{F}_2\text{O}_5\text{PS}^+$ : 451.1514, found: 451.1522.

#### Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluorooctanoate (**5a**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 84.6 mg, 75%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  4.33-4.27 (m, 2H), 4.19-4.05 (m, 4H), 3.49-3.38 (m, 1H), 2.70-2.53 (m, 1H), 2.52-2.34 (m, 1H), 1.85-1.65 (m, 2H), 1.48-1.37 (m, 2H), 1.35-1.28 (m, 11H), 0.90-0.85 (m, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.9 (d,  $J = 32.4$  Hz), 115.2 (t,  $J = 252.0$  Hz), 64.1 (d,  $J = 6.4$  Hz), 64.0 (d,  $J = 6.4$  Hz), 63.3, 41.2 (dd,  $J = 7.4, 3.9$  Hz), 40.8 (qd,  $J = 22.5, 4.2$  Hz), 36.1 (d,  $J = 5.3$  Hz), 28.6, 22.4, 16.2 (dd,  $J = 7.4, 0.8$  Hz), 14.1.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  25.83.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.50 (d,  $J = 262.1$  Hz), -105.71 (d,  $J = 262.1$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{14}\text{H}_{28}\text{F}_2\text{O}_5\text{PS}^+$ : 377.1358, found: 377.1349.

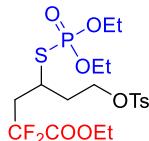
#### Triethyl 3-((diethoxyphosphoryl)thio)-5,5-difluoropentane-1,1,5-tricarboxylate (**5b**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 90.0 mg, 61%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  4.33 (q,  $J = 7.1$  Hz, 2H), 4.26-4.09 (m, 8H), 3.73 (dd,  $J = 9.7, 4.6$  Hz, 1H), 3.56-3.44 (m, 1H), 2.85-2.71 (m, 1H), 2.59-2.45 (m, 2H), 2.24-2.15 (m, 1H), 1.38-1.32 (m, 9H), 1.28-1.24 (m, 6H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  169.0, 168.6, 163.7 (t,  $J = 32.3$  Hz), 115.0 (t,  $J = 252.4$  Hz), 64.2 (d,  $J = 6.6$  Hz), 64.1 (d,  $J = 6.6$  Hz), 63.4, 61.93, 61.90,

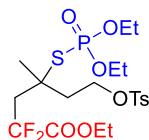
50.0, 41.5 (td,  $J = 22.8, 2.8$  Hz), 39.2 (q,  $J = 3.3$  Hz), 35.2 (d,  $J = 5.7$  Hz), 16.2 (d,  $J = 2.4$  Hz), 16.1 (d,  $J = 2.5$  Hz), 14.2, 14.1, 14.0.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  24.46.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.54 (d,  $J = 263.8$  Hz), -105.20 (d,  $J = 263.8$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{18}\text{H}_{32}\text{F}_2\text{O}_9\text{PS}^+$ : 493.1467, found: 493.1460.

Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-6-(tosyloxy)hexanoate (**5c**)



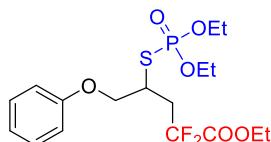
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 91.7 mg, 59%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.77 (d,  $J = 8.1$  Hz, 2H), 7.36-7.32 (m, 2H), 4.31 (q,  $J = 7.1$  Hz, 2H), 4.24-4.03 (m, 6H), 3.55-3.43 (m, 1H), 2.76-2.60 (m, 1H), 2.53-2.38 (m, 1H), 2.43 (s, 3H), 2.27-2.19 (m, 1H), 2.10-2.01 (m, 1H), 1.35-1.30 (m, 9H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.6 (t,  $J = 32.2$  Hz), 145.2, 132.9, 130.1, 128.1, 115.0 (t,  $J = 252.4$  Hz), 67.3, 64.3 (d,  $J = 5.7$  Hz), 64.28 (d,  $J = 6.1$  Hz), 63.5, 40.9 (td,  $J = 22.9, 3.7$  Hz), 37.3-37.2 (m), 35.0 (d,  $J = 4.7$  Hz), 21.8, 16.14 (d,  $J = 4.9$  Hz), 16.10 (d,  $J = 4.9$  Hz), 14.0.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  24.24.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.52 (d,  $J = 263.3$  Hz), -105.35 (d,  $J = 263.3$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{19}\text{H}_{30}\text{F}_2\text{O}_8\text{PS}_2^+$ : 519.1082, found: 519.1077.

Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-4-methyl-6-(tosyloxy)hexanoate (**5d**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 114.9 mg, 72%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.75 (d,  $J = 7.9$  Hz, 2H), 7.32 (d,  $J = 8.0$  Hz, 2H), 4.40-4.24 (m, 4H), 4.14-4.00 (m, 4H), 2.80-0.65 (m, 2H), 2.41 (s, 3H), 2.35-2.22 (m, 2H), 1.56 (s, 3H), 1.33-1.27 (m, 9H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.83 (t,  $J = 32.3$  Hz), 145.1, 132.9, 130.0, 128.0, 115.4 (t,  $J = 253.5$  Hz), 67.2, 64.3 (d,  $J = 1.3$  Hz), 64.2 (d,  $J = 1.3$  Hz), 63.4, 51.9 (d,  $J = 4.2$  Hz), 45.1 (td,  $J = 21.8, 3.7$  Hz), 40.1-39.9 (m), 27.8 (d,  $J = 8.2$  Hz), 21.7, 16.1 (d,  $J = 1.0$  Hz), 16.0 (d,  $J = 1.3$  Hz), 13.9.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  22.0.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -101.09 (d,  $J = 261.5$  Hz), -102.16 (d,  $J = 261.5$  Hz). HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{20}\text{H}_{31}\text{F}_2\text{NaO}_8\text{PS}_2^+$ : 555.1058, found: 555.1047.

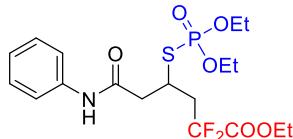
Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-5-phenoxypentanoate (**5e**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 71.6 mg, 56%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.32-7.26 (m, 2H), 7.00-6.95 (m, 1H), 6.94-6.91 (m, 2H), 4.34-4.25 (m, 3H), 4.24-4.10 (m, 5H), 3.88-3.77 (m, 1H), 2.90-2.78 (m, 1H), 2.70-2.55 (m, 1H), 1.37-1.31 (m, 9H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.7 (t,  $J = 32.4$  Hz), 158.2, 129.8,

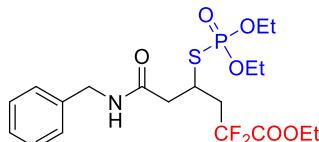
121.7, 115.1 (t,  $J = 252.0$  Hz), 114.8, 70.3 (d,  $J = 2.7$  Hz), 64.3 (d,  $J = 6.4$  Hz), 63.4, 39.3 (q,  $J = 3.6$  Hz), 37.6 (td,  $J = 23.6, 6.8$  Hz), 16.2 (d,  $J = 2.8$  Hz), 16.1 (d,  $J = 2.7$  Hz), 14.1.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  23.30.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.94 (d,  $J = 266.2$  Hz), -104.95 (d,  $J = 266.2$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{17}\text{H}_{26}\text{F}_2\text{O}_6\text{PS}^+$ : 427.1150, found: 427.1155.

Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-6-oxo-6-(phenylamino)hexanoate (**5f**)



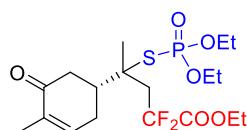
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 93.8 mg, 69%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  8.63 (s, 1H), 7.59-7.55 (m, 2H), 7.31-7.27 (m, 2H), 7.10-7.05 (m, 1H), 4.31 (q,  $J = 7.1$  Hz, 2H), 4.21-4.05 (m, 4H), 3.91-3.81 (m, 1H), 3.04-2.92 (m, 2H), 2.83-2.68 (m, 2H), 1.36-1.29 (m, 9H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.7 (t,  $J = 32.3$  Hz), 138.2, 129.1, 124.3, 119.9, 115.0 (t,  $J = 252.2$  Hz), 64.7 (d,  $J = 6.9$  Hz), 64.6 (d,  $J = 6.9$  Hz), 63.5, 44.0, 40.3 (td,  $J = 23.0, 6.2$  Hz), 37.2-37.0 (m), 16.13 (d,  $J = 5.2$  Hz), 16.09 (d,  $J = 5.3$  Hz), 14.0.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  24.83.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -103.55 (d,  $J = 263.4$  Hz), -105.44 (d,  $J = 263.5$  Hz). HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{18}\text{H}_{26}\text{F}_2\text{NNaO}_6\text{PS}^+$ : 476.1079, found: 476.1069.

Ethyl 6-(benzylamino)-4-((diethoxyphosphoryl)thio)-2,2-difluoro-6-oxohexanoate (**5g**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 84.1 mg, 60%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.26-7.14 (m, 5H), 6.73 (s, 1H), 4.38-4.30 (m, 2H), 4.24 (q,  $J = 7.1$  Hz, 2H), 4.05-3.91 (m, 4H), 3.82-3.69 (m, 1H), 2.75-2.60 (m, 4H), 1.31-1.19 (m, 9H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  169.5, 163.7 (t,  $J = 32.3$  Hz), 138.3, 128.7, 128.0, 127.5, 115.0 (t,  $J = 252.1$  Hz), 64.4 (d,  $J = 6.7$  Hz), 64.3 (d,  $J = 6.7$  Hz), 63.4, 43.6, 42.6, 40.1 (td,  $J = 23.0, 5.4$  Hz), 37.1-36.9 (m), 16.1 (d,  $J = 7.2$  Hz), 14.0.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  24.84.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -103.26 (d,  $J = 262.8$  Hz), -105.52 (d,  $J = 262.8$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{19}\text{H}_{29}\text{F}_2\text{NO}_6\text{PS}^+$ : 468.1416, found: 468.1422.

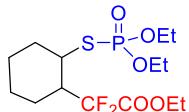
Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-4-((R)-4-methyl-5-oxocyclohex-3-en-1-yl)pentanoate (**5h**, dr = 1:1)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 88.8 mg, 67%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  6.73-6.69 (m, 1H), 4.30-4.24 (m, 2H), 4.17-4.04 (m, 4H), 3.09-2.93 (m, 1H), 2.82-2.49 (m, 4H), 2.44-2.27 (m, 2H), 1.73 (s, 3H), 1.69 (s, 3H), 1.34-1.26 (m, 9H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  198.9, 198.5, 163.9 (t,  $J = 32.9$  Hz), 144.32,

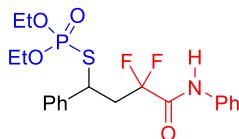
144.30, 135.53, 135.50, 115.5 (t,  $J$  = 252.1 Hz), 115.6 (t,  $J$  = 252.1 Hz), 64.40 (d,  $J$  = 7.0 Hz), 64.36 (d,  $J$  = 2.9 Hz), 64.32 (d,  $J$  = 3.8 Hz), 64.30 (d,  $J$  = 3.6 Hz), 63.4, 56.6 (d,  $J$  = 4.3 Hz), 56.5 (d,  $J$  = 4.4 Hz), 44.5 (d,  $J$  = 5.8 Hz), 44.2 (d,  $J$  = 7.5 Hz), 42.3-41.8 (m), 40.0, 39.9, 28.0, 27.96, 26.0-25.9 (m), 25.9-25.7 (m), 16.2 (d,  $J$  = 2.0 Hz), 16.12 (d,  $J$  = 2.1 Hz), 16.09 (d,  $J$  = 3.0 Hz), 16.07 (d,  $J$  = 4.2 Hz), 15.6, 14.0.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  22.66, 22.56.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -100.49 (d,  $J$  = 260.6 Hz), -102.51 (d,  $J$  = 260.9 Hz), -103.22 (d,  $J$  = 260.2 Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{18}\text{H}_{30}\text{F}_2\text{O}_6\text{PS}^+$ : 443.1463, found: 443.1458.

Ethyl 2-((diethoxyphosphoryl)thio)cyclohexyl)-2,2-difluoroacetate (**5i**, dr = 3:1)



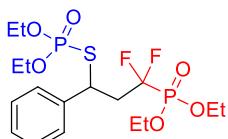
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 30.3 mg, 27%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  4.36-4.29 (m, 2H), 4.21-4.08 (m, 4H), 3.96-3.90 (m, 0.2 H), 3.35-3.29 (m, 0.6 H), 2.60-1.90 (m, 3H), 1.85-1.45 (m, 5H), 1.40-1.30 (m, 10H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  164.4 (t,  $J$  = 32.9 Hz), 116.3 (t,  $J$  = 257.6 Hz), 63.91 (d,  $J$  = 1.7 Hz), 63.85 (d,  $J$  = 1.8 Hz), 63.7 (d,  $J$  = 6.3 Hz), 63.6 (d,  $J$  = 4.2 Hz), 63.3, 63.2, 46.5 (td,  $J$  = 22.0, 7.5 Hz), 45.4 (td,  $J$  = 21.5, 7.0 Hz), 43.8-43.7 (m), 42.8-42.7 (m), 35.8, 34.4, 25.3, 25.1, 24.8, 24.5-24.4 (m), 23.8, 20.5, 19.5, 16.2 (d,  $J$  = 1.5 Hz), 16.1 (d,  $J$  = 1.6 Hz), 14.1, 14.0.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  26.62, 25.49.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -105.96 (d,  $J$  = 266.0 Hz), -108.32 (d,  $J$  = 264.3 Hz), -109.42 (d,  $J$  = 263.9 Hz), -114.01 (d,  $J$  = 266.4 Hz). HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{14}\text{H}_{25}\text{F}_2\text{NaO}_5\text{PS}^+$ : 397.1021, found: 397.1027.

S-(3,3-difluoro-4-oxo-1-phenyl-4-(phenylamino)butyl)  $O,O$ -diethyl phosphorothioate (**6a**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 79.7 mg, 60%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  8.44 (s, 1H), 7.52-7.48 (m, 2H), 7.37-7.25 (m, 6H), 7.22-7.12 (m, 2H), 4.64-4.57 (m, 1H), 4.03-3.93 (m, 1H), 3.90-3.84 (m, 2H), 3.82-3.71 (m, 1H), 3.13-2.90 (m, 2H), 1.15 (t,  $J$  = 7.1 Hz, 3H), 1.13 (t,  $J$  = 7.2 Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  161.5 (t,  $J$  = 28.1 Hz), 141.0 (d,  $J$  = 3.6 Hz), 136.3, 129.1, 128.8, 127.6, 125.5, 120.5, 116.5 (t,  $J$  = 255.8 Hz), 63.94 (d,  $J$  = 2.5 Hz), 63.90 (d,  $J$  = 2.0 Hz), 44.0 (dd,  $J$  = 7.4, 4.2 Hz), 41.6 (td,  $J$  = 23.7, 8.1 Hz), 15.9 (d,  $J$  = 8.0 Hz), 15.8 (d,  $J$  = 8.0 Hz).  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  24.20.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.80 (d,  $J$  = 258.1 Hz), -103.82 (d,  $J$  = 258.2 Hz). HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{20}\text{H}_{24}\text{F}_2\text{NNaO}_4\text{PS}^+$ : 466.1024, found: 466.1018.

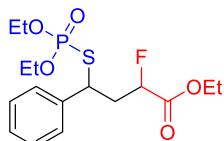
S-(3-(diethoxyphosphoryl)-3,3-difluoro-1-phenylpropyl)  $O,O$ -diethyl phosphorothioate (**6b**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 1:1); Yield: 110.4

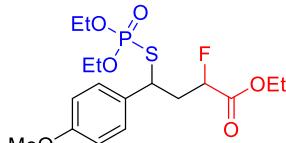
mg, 80%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.39-7.25 (m, 5H), 4.74-4.67 (m, 1H), 4.30-4.19 (m, 4H), 4.10-3.93 (m, 3H), 3.84-3.76 (m, 1H), 3.00-2.18 (m, 2H), 1.38-1.33 (m, 6H), 1.26 (t,  $J = 7.1$  Hz, 3H), 1.18 (t,  $J = 7.2$  Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  141.7 (d,  $J = 3.9$  Hz), 128.6, 127.9, 127.5, 119.3 (td,  $J = 262.4, 215.4$  Hz), 64.8 (d,  $J = 3.7$  Hz), 64.76 (d,  $J = 3.9$  Hz), 63.65 (d,  $J = 5.9$  Hz), 63.55 (d,  $J = 5.6$  Hz), 43.2-43.0 (m), 41.6-40.9 (m), 16.4 (d,  $J = 5.3$  Hz), 15.9 (d,  $J = 7.5$  Hz), 15.8 (d,  $J = 7.5$  Hz).  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  24.26 (s, 1P), 6.07 (t,  $J = 105.1$  Hz, 1P).  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -111.01 (dd,  $J = 298.1, 105.4$  Hz), -112.73 (dd,  $J = 298.1, 105.0$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{17}\text{H}_{29}\text{F}_2\text{O}_6\text{P}_2\text{S}^+$ : 461.1123, found: 461.1113.

Ethyl 4-((diethoxyphosphoryl)thio)-2-fluoro-4-phenylbutanoate (**6c**, dr = 1.4:1)



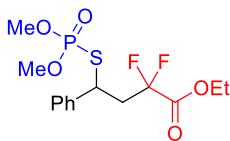
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 83.9 mg, 74%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.38-7.27 (m, 5H), 5.26-5.12 (m, 0.54H), 4.55-4.41 (m, 1.38H), 4.24-4.01 (m, 5H), 3.82-3.65 (m, 1H), 2.68-2.46 (m, 2H), 1.34-1.22 (m, 6H), 1.18-1.06 (m, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  169.14 (d,  $J = 23.2$  Hz), 169.13 (d,  $J = 23.2$  Hz), 141.6 (d,  $J = 2.1$  Hz), 140.0 (d,  $J = 3.7$  Hz), 129.0, 128.8, 128.3, 128.1, 127.9, 127.6, 86.5 (d,  $J = 186.1$  Hz), 86.4 (d,  $J = 186.1$  Hz), 63.7 (d,  $J = 5.7$  Hz), 63.6 (d,  $J = 6.7$  Hz), 63.5 (d,  $J = 5.7$  Hz), 61.9, 46.2 (t,  $J = 3.4$  Hz), 45.9-45.8 (m), 40.8-40.2 (m), 16.0 (d,  $J = 4.0$  Hz), 15.9 (d,  $J = 4.3$  Hz), 15.86 (d,  $J = 7.9$  Hz), 15.8 (d,  $J = 7.8$  Hz), 14.2, 14.1.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  24.61, 24.60.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -193.20, -194.48. HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{16}\text{H}_{25}\text{FO}_5\text{PS}^+$ : 379.1139, found: 379.1136.

Ethyl 4-((diethoxyphosphoryl)thio)-2-fluoro-4-phenylbutanoate (**6d**, dr = 1.4:1)



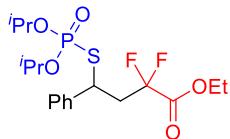
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 91.8 mg, 75%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.31-7.28 (m, 2H), 6.90-6.85 (m, 2H), 5.21-5.08 (m, 0.55H), 4.55-4.42 (m, 1.38H), 4.24-4.10 (m, 2H), 4.10-3.96 (m, 3H), 3.89-3.73 (m, 4H), 2.69-2.42 (m, 2H), 1.30-1.26 (m, 6H), 1.22-1.15 (m, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  169.3 (d,  $J = 23.3$  Hz), 159.5 (d,  $J = 23.1$  Hz), 133.7 (d,  $J = 2.7$  Hz), 131.9 (d,  $J = 4.2$  Hz), 129.13, 128.9, 114.5, 114.1, 86.7 (d,  $J = 186.1$  Hz), 86.5 (d,  $J = 186.1$  Hz), 63.8 (d,  $J = 5.7$  Hz), 63.7 (d,  $J = 6.4$  Hz), 63.6 (d,  $J = 5.9$  Hz), 61.9, 55.5, 46.0 (t,  $J = 3.5$  Hz), 45.7-45.6 (m), 40.8 (td,  $J = 21.5, 8.4$  Hz), 16.1 (d,  $J = 4.9$  Hz), 16.0 (d,  $J = 3.3$  Hz), 15.99 (d,  $J = 5.8$  Hz), 15.9 (d,  $J = 7.6$  Hz), 14.24, 14.21.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  24.82, 24.81.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -192.93, -194.45. HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{17}\text{H}_{26}\text{FNaO}_6\text{PS}^+$ : 431.1064, found: 431.1057.

Ethyl 4-((dimethoxyphosphoryl)thio)-2,2-difluoro-4-phenylbutanoate (**6e**)



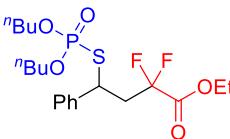
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 55.2 mg, 50%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.38-7.31 (m, 4H), 7.30-7.25 (m, 1H), 4.53-4.45 (m, 1H), 4.04 (q, *J* = 7.1 Hz, 2H), 3.64 (d, *J* = 12.8 Hz, 3H), 3.52 (d, *J* = 12.8 Hz, 3H), 2.96-2.85 (m, 2H), 1.25 (t, *J* = 7.1 Hz, 3H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>) δ 163.2 (t, *J* = 32.2 Hz), 140.3 (d, *J* = 3.6 Hz), 128.7, 128.3, 127.7, 114.3 (t, *J* = 253.8 Hz), 63.1, 53.8 (d, *J* = 5.6 Hz), 53.6 (d, *J* = 5.4 Hz), 44.0-43.8 (m), 42.13 (td, *J* = 23.8, 8.3 Hz), 13.7. <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>) δ 27.47. <sup>19</sup>F NMR (471 MHz, CDCl<sub>3</sub>) δ -102.74 (d, *J* = 265.7 Hz), -105.15 (d, *J* = 265.7 Hz). HRMS: [M+Na]<sup>+</sup> *m/z* calcd for C<sub>14</sub>H<sub>19</sub>F<sub>2</sub>NaO<sub>5</sub>PS<sup>+</sup>: 391.0551, found: 391.0544.

#### Ethyl 4-((diisopropoxyphosphoryl)thio)-2,2-difluoro-4-phenylbutanoate (**6f**)



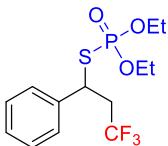
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 114.5 mg, 90%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.36-7.29 (m, 4H), 7.28-7.24 (m, 1H), 4.71-4.63 (m, 1H), 4.60-4.48 (m, 2H), 4.00-3.92 (m, 2H), 3.08-2.86 (m, 2H), 1.32 (d, *J* = 6.2 Hz, 3H), 1.25-1.19 (m, 12H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>) δ 163.4 (t, *J* = 32.3 Hz), 140.3 (d, *J* = 5.1 Hz), 128.8, 128.3, 128.0, 114.5 (dd, *J* = 253.3, 250.8 Hz), 73.24 (d, *J* = 6.4 Hz), 73.18 (d, *J* = 6.8 Hz), 63.0, 44.2-44.1 (m), 42.5 (td, *J* = 23.6, 6.7 Hz), 23.9 (d, *J* = 3.9 Hz), 23.8 (d, *J* = 4.1 Hz), 23.6 (d, *J* = 5.7 Hz), 23.5 (d, *J* = 5.7 Hz), 13.8. <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>) δ 21.61. <sup>19</sup>F NMR (471 MHz, CDCl<sub>3</sub>) δ -101.82 (d, *J* = 265.0 Hz), -105.74 (d, *J* = 265.0 Hz). HRMS: [M+Na]<sup>+</sup> *m/z* calcd for C<sub>18</sub>H<sub>27</sub>F<sub>2</sub>NaO<sub>5</sub>PS<sup>+</sup>: 447.1177, found: 447.1173.

#### Ethyl 4-((dibutoxyphosphoryl)thio)-2,2-difluoro-4-phenylbutanoate (**6g**)



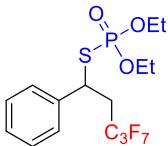
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 120.7 mg, 89%; Colourless liquid; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.37-7.24 (m, 5H), 4.57-4.47 (m, 1H), 4.04-3.83 (m, 5H), 3.78-3.70 (m, 1H), 2.99-2.82 (m, 2H), 1.61-1.46 (m, 4H), 1.38-1.28 (m, 4H), 1.27-1.19 (m, 3H), 0.92-0.85 (m, 6H). <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>) δ 163.3 (t, *J* = 32.2 Hz), 140.5 (d, *J* = 3.8 Hz), 114.4 (t, *J* = 253.8 Hz), 128.7, 128.2, 127.9, 67.44 (d, *J* = 6.2 Hz), 67.40 (d, *J* = 5.1 Hz), 44.0-43.9 (m), 42.4 (td, *J* = 23.8, 7.8 Hz), 32.0 (t, *J* = 7.5 Hz), 18.7 (d, *J* = 1.5 Hz), 13.8, 13.6. <sup>31</sup>P NMR (243 MHz, CDCl<sub>3</sub>) δ 24.07. <sup>19</sup>F NMR (471 MHz, CDCl<sub>3</sub>) δ -102.34 (d, *J* = 265.6 Hz), -105.38 (d, *J* = 265.6 Hz). HRMS: [M+H]<sup>+</sup> *m/z* calcd for C<sub>20</sub>H<sub>32</sub>F<sub>2</sub>O<sub>5</sub>PS<sup>+</sup>: 453.1671, found: 453.1681.

#### O,O-diethyl S-(3,3,3-trifluoro-1-phenylpropyl) phosphorothioate (**7a**)



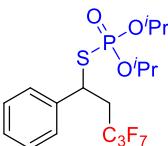
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 41.0 mg, 40%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.36-7.33 (m, 4H), 7.30-7.27 (m, 1H), 4.56-4.52 (m, 1H), 4.12-3.94 (m, 3H), 3.90-3.83 (m, 1H), 3.02-2.94 (m, 1H), 2.89-2.80 (m, 1H), 1.25 (t,  $J$  = 7.1 Hz, 3H), 1.21 (t,  $J$  = 7.1 Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  140.5 (d,  $J$  = 4.5 Hz), 129.0, 128.5, 127.5, 125.2 (q,  $J$  = 278.4 Hz), 64.04 (d,  $J$  = 4.6 Hz), 64.00 (d,  $J$  = 4.2 Hz), 44.0 - 43.9 (m), 42.0 (qd,  $J$  = 28.2, 7.4 Hz), 16.1 (d,  $J$  = 6.2 Hz), 16.0 (d,  $J$  = 6.2 Hz).  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  23.82.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -63.79. HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{13}\text{H}_{18}\text{F}_3\text{NaO}_3\text{PS}^+$ : 365.0559, found: 365.0553.

*O,O*-diethyl S-(3,3,4,4,5,5-heptafluoro-1-phenylpentyl) phosphorothioate (**7b**)



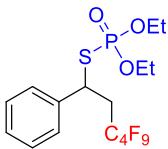
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 69.0 mg, 52%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.38-7.31 (m, 4H), 7.31-7.26 (m, 1H), 4.69-4.62 (m, 1H), 4.13-3.94 (m, 3H), 3.93-3.82 (m, 1H), 3.07-2.74 (m, 2H), 1.25 (t,  $J$  = 6.0 Hz, 3H), 1.22 (t,  $J$  = 6.0 Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  140.8 (d,  $J$  = 4.8 Hz), 129.1, 128.4, 127.5, 64.01 (d,  $J$  = 4.4 Hz), 63.95 (d,  $J$  = 4.1 Hz), 43.1-42.9 (m), 38.3 (td,  $J$  = 20.7, 6.8 Hz), 16.0, 15.9.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  23.72.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -81.37 - -81.43 (m, 3F), -112.74 - -113.54 (m, 1F), -114.47 - -115.28 (m, 1F), -127.83 (dd,  $J$  = 13.7, 5.1 Hz, 2F). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{15}\text{H}_{19}\text{F}_7\text{O}_3\text{PS}^+$ : 443.0675, found: 443.0673.

S-(3,3,4,4,5,5-heptafluoro-1-phenylpentyl) *O,O*-diisopropyl phosphorothioate (**7c**)



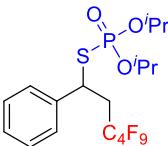
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 102.9 mg, 73%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.43-7.25 (m, 5H), 4.78-4.65 (m, 2H), 4.63-4.53 (m, 1H), 3.18-2.72 (m, 2H), 1.36-1.23 (m, 12H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  140.6 (d,  $J$  = 6.2 Hz), 129.0, 128.4, 127.5, 73.43 (d,  $J$  = 2.0 Hz), 73.36 (d,  $J$  = 2.3 Hz), 43.3-43.1 (m, 38.4 (td,  $J$  = 20.5, 5.6 Hz), 23.9 (d,  $J$  = 4.0 Hz), 23.8 (d,  $J$  = 4.2 Hz), 23.61 (d,  $J$  = 4.3 Hz), 23.56 (d,  $J$  = 4.3 Hz).  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  21.51.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -80.44 (t,  $J$  = 9.7 Hz, 3F), -112.30 - -113.14 (m, 1F), -114.73 - -115.57 (m, 1F), -127.85 (dd,  $J$  = 5.9, 5.1 Hz, 2F). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{17}\text{H}_{23}\text{F}_7\text{O}_3\text{PS}^+$ : 471.0988, found: 471.0966.

*O,O*-diethyl S-(3,3,4,4,5,5,6,6,6-nonafluoro-1-phenylhexyl) phosphorothioate (**7d**)



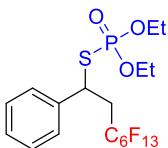
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 59.0 mg, 40%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.37-7.33 (m, 4H), 7.30-7.26 (m, 1H), 4.69-4.64 (m, 1H), 4.12-3.95 (m, 3H), 3.92-3.85 (m, 1H), 3.05-2.95 (m, 1H), 2.90-2.80 (m, 1H), 1.26-1.21 (m, 6H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  140.8 (d,  $J$  = 4.8 Hz), 129.1, 128.4, 127.5, 64.0 (d,  $J$  = 6.0 Hz), 63.96 (d,  $J$  = 5.7 Hz), 43.1-43.0 (m), 38.6 (td,  $J$  = 20.5, 6.8 Hz), 15.99 (d,  $J$  = 7.5 Hz).  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  23.68.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -81.10 – -81.22 (m, 3F), -112.30 (dt,  $J$  = 272.0, 13.0 Hz, 1F), -114.03 (dt,  $J$  = 272.0, 11.3 Hz, 1F), -124.40 – -124.60 (m, 2F), -125.94 – -126.08 (m, 2F). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{16}\text{H}_{19}\text{F}_9\text{O}_3\text{PS}^+$ : 493.0643, found: 493.0636.

#### *O,O*-diisopropyl *S*-(3,3,4,4,5,5,6,6,6-nonafluoro-1-phenylhexyl) phosphorothioate (**7e**)



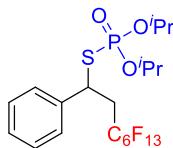
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 99.8 mg, 64%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.38-7.34 (m, 4H), 7.30-7.28 (m, 1H), 4.75-4.68 (m, 2H), 4.62-4.56 (m, 1H), 3.17-3.08 (m, 1H), 2.95-2.84 (m, 1H), 1.35 (d,  $J$  = 6.2 Hz, 3H), 1.28-1.24 (m, 9H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  140.7 (d,  $J$  = 6.2 Hz), 129.0, 128.4, 127.5, 73.40 (d,  $J$  = 4.1 Hz), 73.36 (d,  $J$  = 4.5 Hz), 43.3-43.2 (m), 38.6 (td,  $J$  = 20.5, 5.5 Hz), 23.9 (d,  $J$  = 4.1 Hz), 23.8 (d,  $J$  = 4.2 Hz), 23.6 (d,  $J$  = 5.6 Hz), 23.57 (d,  $J$  = 5.6 Hz).  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  21.43.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -81.16 – -81.24 (m, 3F), -111.97 (dt,  $J$  = 272.0, 13.0 Hz, 1F), -114.23 (dt,  $J$  = 272.0, 11.3 Hz, 1F), -124.46 – -124.56 (m, 2F), -125.94 – -126.04 (m, 2F). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{18}\text{H}_{23}\text{F}_9\text{O}_3\text{PS}^+$ : 521.0956, found: 521.0947.

#### *O,O*-diethyl *S*-(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluoro-1-phenyloctyl) phosphorothioate (**7f**)



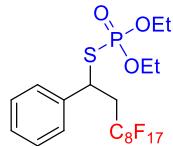
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 78.1 mg, 44%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.37-7.33 (m, 4H), 7.30-7.27 (m, 1H), 4.69-4.64 (m, 1H), 4.12-3.95 (m, 3H), 3.92-3.85 (m, 1H), 3.04-2.95 (m, 1H), 2.90-2.80 (m, 1H), 1.26-1.21 (m, 6H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  140.7 (d,  $J$  = 4.8 Hz), 128.9, 128.2, 127.3, 63.8 (d,  $J$  = 6.0 Hz), 63.77 (d,  $J$  = 5.7 Hz), 42.9-42.8 (m), 38.5 (td,  $J$  = 20.6, 6.8 Hz), 15.8 (d,  $J$  = 7.3 Hz).  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  23.69.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -80.87 – -80.94 (m, 3F), -112.10 (dt,  $J$  = 272.0, 13.0 Hz, 1F), -113.85 (dt,  $J$  = 272.0, 11.3 Hz, 1F), -121.77 – -121.95 (m, 2F), -122.80 – -123.05 (m, 2F), -123.45 – -123.65 (m, 2F), -126.15 – -126.25 (m, 2F). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{18}\text{H}_{19}\text{F}_{13}\text{O}_3\text{PS}^+$ : 593.0579, found: 593.0578.

*O,O*-diisopropyl *S*-(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluoro-1-phenyloctyl) phosphorothioate (**7g**)



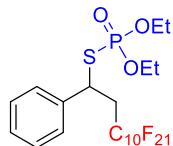
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 124.6 mg, 67%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.36-7.34 (m, 4H), 7.28-7.26 (m, 1H), 4.73-4.66 (m, 2H), 4.60-4.54 (m, 1H), 3.14-3.05 (m, 1H), 2.92-2.82 (m, 1H), 1.32 (d,  $J$  = 6.2 Hz, 3H), 1.26-1.23 (m, 9H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  140.7 (d,  $J$  = 6.1 Hz), 129.1, 128.4, 127.5, 73.44 (d,  $J$  = 3.9 Hz), 73.4 (d,  $J$  = 4.3 Hz), 43.4-43.3 (m), 38.7 (td,  $J$  = 20.6, 5.3 Hz), 23.9 (d,  $J$  = 3.9 Hz), 23.8 (d,  $J$  = 4.0 Hz), 23.62 (d,  $J$  = 5.8 Hz), 23.58 (d,  $J$  = 5.7 Hz).  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  21.48.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -80.70 – -81.30 (m, 3F), -111.75 (dt,  $J$  = 272.0, 13.0 Hz, 1F), -113.99 (dt,  $J$  = 272.0, 11.3 Hz, 1F), -121.66 – -121.98 (m, 2F), -122.75 – -123.10 (m, 2F), -123.50 – -123.75 (m, 2F), -126.12 – -126.48 (m, 2F). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{20}\text{H}_{23}\text{F}_{13}\text{O}_3\text{PS}^+$ : 621.0892, found: 621.0885.

*O,O*-diethyl *S*-(3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-heptadecafluoro-1-phenyldecyl) phosphorothioate (**7h**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 114.2 mg, 55%; Colourless gum;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.37-7.33 (m, 4H), 7.29-7.26 (m, 1H), 4.69-4.64 (m, 1H), 4.12-3.95 (m, 3H), 3.92-3.86 (m, 1H), 3.03-2.96 (m, 1H), 2.90-2.80 (m, 1H), 1.26-1.21 (m, 6H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  140.9 (d,  $J$  = 4.8 Hz), 129.1, 128.4, 127.5, 64.0 (d,  $J$  = 6.1 Hz), 63.98 (d,  $J$  = 5.8 Hz), 43.16-43.04 (m), 38.7 (td,  $J$  = 20.5, 6.9 Hz), 16.0 (d,  $J$  = 7.4 Hz).  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  23.71.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -80.92 – -81.02 (m, 3F), -112.16 (dt,  $J$  = 272.0, 13.0 Hz, 1F), -113.76 (dt,  $J$  = 272.0, 11.3 Hz, 1F), -121.55 – -122.70 (m, 2F), -121.80 – -122.05 (m, 6F), -122.75 – -123.10 (m, 2F), -123.50 – -123.75 (m, 2F), -126.12 – -126.48 (m, 2F). HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{20}\text{H}_{18}\text{F}_{17}\text{NaO}_3\text{PS}^+$ : 715.0335, found: 715.0333.

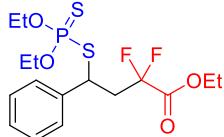
*O,O*-diethyl *S*-(3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,12-henicosafuoro-1-phenyldodecyl) phosphorothioate (**7i**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 104.5 mg, 44%; Colourless gum;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.37-7.33 (m, 4H), 7.29-7.26 (m, 1H), 4.69-4.64 (m, 1H), 4.12-3.95 (m, 3H), 3.92-3.85 (m, 1H), 3.04-2.95 (m, 1H), 2.90-2.80 (m, 1H), 1.26-1.21 (m, 6H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  140.9 (d,  $J$  = 4.7 Hz), 129.1, 128.4, 127.5, 64.02 (d,  $J$  = 6.0 Hz), 63.98 (d,  $J$  = 5.8 Hz), 43.15-43.05 (m), 38.7 (td,  $J$  = 20.6, 6.8 Hz), 16.0 (d,  $J$  = 7.4 Hz).

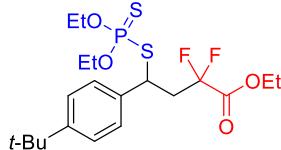
Hz).  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  23.72.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -80.96 – -81.02 (m, 3F), -112.16 (dt,  $J$  = 272.0, 13.0 Hz, 1F), -113.76 (dt,  $J$  = 272.0, 11.3 Hz, 1F), -121.60 – -122.10 (m, 10F), -121.70 – -122.90 (m, 2F), -123.46 – -123.64 (m, 2F), -126.19 – -126.35 (m, 2F). HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{22}\text{H}_{18}\text{F}_{21}\text{NaO}_3\text{PS}^+$ : 815.0271, found: 815.0276.

Ethyl 4-((diethoxyphosphorothioyl)thio)-2,2-difluoro-4-phenylbutanoate (**8a**)



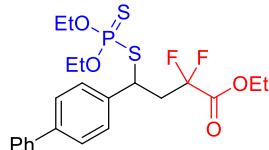
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 30:1); Yield: 100.1 mg, 81%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.35-7.24 (m, 5H), 4.57-4.47 (m, 1H), 4.15-3.94 (m, 5H), 3.78-3.68 (m, 1H), 2.93-2.83 (m, 2H), 1.28 (t,  $J$  = 7.1 Hz, 3H), 1.24 (t,  $J$  = 7.2 Hz, 3H), 1.16 (t,  $J$  = 7.1 Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.4 (t,  $J$  = 32.2 Hz), 140.4 (d,  $J$  = 4.0 Hz), 128.8, 128.3, 128.0, 114.5 (t,  $J$  = 252.0 Hz), 64.3 (d,  $J$  = 5.9 Hz), 64.1 (d,  $J$  = 5.5 Hz), 63.2, 46.5-46.3 (m), 42.4 (td,  $J$  = 23.6, 6.8 Hz), 15.8 (d,  $J$  = 8.7 Hz), 15.7 (d,  $J$  = 8.8 Hz), 13.9.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  89.62.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.34 (d,  $J$  = 264.9 Hz), -105.13 (d,  $J$  = 264.9 Hz). HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{16}\text{H}_{23}\text{F}_2\text{NaO}_4\text{PS}_2^+$ : 435.0636, found: 435.0640.

Ethyl 4-(4-(tert-butyl)phenyl)-4-((diethoxyphosphorothioyl)thio)-2,2-difluorobutanoate (**8b**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 30:1); Yield: 109.5 mg, 78%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.35-7.31 (m, 2H), 7.27-7.24 (m, 2H), 4.53-4.46 (m, 1H), 4.13-3.88 (m, 5H), 3.76-3.65 (m, 1H), 2.93-2.82 (m, 2H), 1.29 (s, 9H), 1.28 (t,  $J$  = 7.2 Hz, 3H), 1.20 (t,  $J$  = 7.2 Hz, 3H), 1.14 (t,  $J$  = 7.1 Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.4 (t,  $J$  = 32.2 Hz), 151.4, 137.1 (d,  $J$  = 4.0 Hz), 127.8, 125.7, 114.6 (dd,  $J$  = 253.0, 251.0 Hz), 64.3 (d,  $J$  = 5.8 Hz), 64.1 (d,  $J$  = 5.4 Hz), 63.1, 46.3-46.1 (m), 42.4 (td,  $J$  = 23.9, 7.2 Hz), 34.8, 31.4, 15.9 (d,  $J$  = 8.8 Hz), 15.7 (d,  $J$  = 9.1 Hz), 13.9.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  89.59.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -101.65 (d,  $J$  = 264.5 Hz), -105.82 (d,  $J$  = 264.5 Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{20}\text{H}_{32}\text{F}_2\text{O}_4\text{PS}_2^+$ : 469.1442, found: 469.1437.

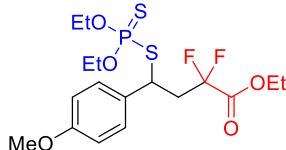
Ethyl 4-([1,1'-biphenyl]-4-yl)-4-((diethoxyphosphorothioyl)thio)-2,2-difluorobutanoate (**8c**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 30:1); Yield: 112.7 mg, 77%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.60-7.56 (m, 4H), 7.47-7.41 (m, 4H), 7.39-7.34 (m, 1H), 4.64-4.57 (m, 1H), 4.18-3.98 (m, 5H), 3.85-3.74 (m, 1H), 2.99-2.89 (m, 2H), 1.30 (t,  $J$  = 7.1 Hz, 3H), 1.24 (t,  $J$  = 7.2 Hz, 3H), 1.19 (t,  $J$  = 7.1 Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.4 (t,  $J$  = 32.2 Hz), 141.1, 140.4, 139.3 (d,  $J$  = 4.0 Hz), 129.0, 128.4, 127.7, 127.4,

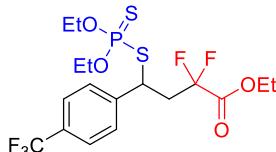
127.1, 114.5 (t,  $J = 252.0$  Hz), 64.3 (d,  $J = 5.9$  Hz), 64.1 (d,  $J = 5.5$  Hz), 63.2, 46.3-46.1 (m), 42.3 (td,  $J = 23.8, 7.2$  Hz), 15.8 (d,  $J = 8.7$  Hz), 15.7 (d,  $J = 8.9$  Hz), 13.9.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  89.56.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.15 (d,  $J = 264.6$  Hz), -105.10 (d,  $J = 264.6$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{22}\text{H}_{28}\text{F}_2\text{O}_4\text{PS}_2^+$ : 489.1129, found: 489.1133.

Ethyl 4-((diethoxyphosphorothioyl)thio)-2,2-difluoro-4-(4-methoxyphenyl)butanoate (**8d**)



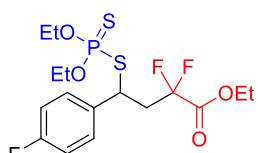
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 30:1); Yield: 100.8 mg, 76%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.26-7.24 (m, 2H), 6.86-6.82 (m, 2H), 4.54-4.50 (m, 1H), 4.15-4.07 (m, 2H), 4.06-3.99 (m, 3H), 3.85-3.80 (m, 1H), 3.79 (s, 3H), 2.92-2.85 (m, 2H), 1.30 (t,  $J = 7.2$  Hz, 3H), 1.25 (t,  $J = 7.2$  Hz, 3H), 1.22 (t,  $J = 7.2$  Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.4 (t,  $J = 32.2$  Hz), 159.5, 132.1 (d,  $J = 4.5$  Hz), 129.2, 114.5 (t,  $J = 252.0$  Hz), 114.1, 64.2 (d,  $J = 5.9$  Hz), 64.1 (d,  $J = 5.6$  Hz), 63.1, 55.5, 46.2-46.1 (m), 42.5 (td,  $J = 23.6, 6.7$  Hz), 15.8 (d,  $J = 8.7$  Hz), 15.7 (d,  $J = 8.8$  Hz), 13.9.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  89.97.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.18 (d,  $J = 264.4$  Hz), -105.30 (d,  $J = 264.4$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{17}\text{H}_{26}\text{F}_2\text{O}_5\text{PS}_2^+$ : 443.0922, found: 443.0920.

Ethyl 4-((diethoxyphosphorothioyl)thio)-2,2-difluoro-4-(4-(trifluoromethyl)phenyl)butanoate (**8e**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 30:1); Yield: 115.2 mg, 80%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.59-7.57 (m, 2H), 7.48-7.46 (m, 2H), 4.62-4.56 (m, 1H), 4.14-4.02 (m, 4H), 3.99-3.94 (m, 1H), 3.81-3.76 (m, 1H), 2.94-2.79 (m, 2H), 1.25 (t,  $J = 7.1$  Hz, 3H), 1.23 (t,  $J = 7.2$  Hz, 3H), 1.16 (t,  $J = 7.1$  Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.3 (t,  $J = 32.1$  Hz), 144.8-144.7 (m), 130.4 (q,  $J = 32.7$  Hz), 128.5, 125.8 (q,  $J = 3.7$  Hz), 124.0 (q,  $J = 272.1$  Hz), 114.4 (t,  $J = 252.8$  Hz), 64.5 (d,  $J = 6.2$  Hz), 64.4 (d,  $J = 5.7$  Hz), 63.4, 46.0-45.9 (m), 42.0 (td,  $J = 23.7, 7.8$  Hz), 15.8 (d,  $J = 8.6$  Hz), 15.7 (d,  $J = 8.8$  Hz), 13.9.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  89.21.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -62.78 (s), -103.13 (d,  $J = 265.6$  Hz), -104.40 (d,  $J = 265.8$  Hz). HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{17}\text{H}_{22}\text{F}_5\text{NaO}_4\text{PS}_2^+$ : 503.0509, found: 503.0511.

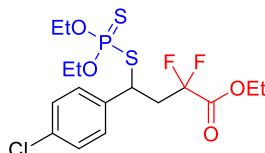
Ethyl 4-((diethoxyphosphorothioyl)thio)-2,2-difluoro-4-(4-fluorophenyl)butanoate (**8f**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 30:1); Yield: 101.9 mg, 79%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.36-7.27 (m, 2H), 7.03-6.96 (m, 2H), 4.55-4.48 (m, 1H), 4.15-3.92 (m, 5H), 3.83-3.72 (m, 1H), 2.92-2.74 (m, 2H), 1.27-1.23 (m, 6H),

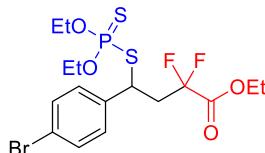
1.18 (t,  $J = 7.1$  Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.4 (t,  $J = 32.2$  Hz), 162.4 (d,  $J = 247.7$  Hz), 136.3 (t,  $J = 3.7$  Hz), 129.7 (d,  $J = 8.2$  Hz), 115.6 (d,  $J = 21.7$  Hz), 114.4 (t,  $J = 252.0$  Hz), 64.3 (d,  $J = 6.0$  Hz), 64.2 (d,  $J = 5.7$  Hz), 63.3, 45.9-45.7 (m), 42.3 (td,  $J = 23.7, 7.3$  Hz), 15.8 (d,  $J = 8.1$  Hz), 15.7 (d,  $J = 8.0$  Hz), 13.9.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  89.55.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.77 (d,  $J = 265.1$  Hz), -104.89 (d,  $J = 265.0$  Hz), -113.48 (s). HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{16}\text{H}_{22}\text{F}_3\text{NaO}_4\text{PS}_2^+$ : 453.0541, found: 453.0532.

#### Ethyl 4-(4-chlorophenyl)-4-((diethoxyphosphorothioyl)thio)-2,2-difluorobutanoate (**8g**)



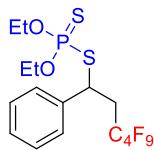
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 30:1); Yield: 108.4 mg, 81%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.25-7.20 (m, 4H), 4.48-4.41 (m, 1H), 4.04-3.87 (m, 5H), 3.78-3.68 (m, 1H), 2.84-2.70 (m, 2H), 1.22-1.18 (m, 6H), 1.12 (t,  $J = 7.1$  Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.3 (t,  $J = 32.1$  Hz), 139.0 (d,  $J = 3.9$  Hz), 134.0, 129.4, 128.9, 114.4 (t,  $J = 252.0$  Hz), 64.3 (d,  $J = 6.1$  Hz), 64.2 (d,  $J = 5.7$  Hz), 63.3, 45.9-45.7 (m), 42.1 (td,  $J = 23.6, 7.4$  Hz), 15.8 (d,  $J = 8.4$  Hz), 15.7 (d,  $J = 8.5$  Hz), 13.9.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  89.40.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.87 (d,  $J = 265.1$  Hz), -104.71 (d,  $J = 265.2$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{16}\text{H}_{23}\text{ClF}_2\text{O}_4\text{PS}_2^+$ : 447.0426, found: 447.0416.

#### Ethyl 4-(4-bromophenyl)-4-((diethoxyphosphorothioyl)thio)-2,2-difluorobutanoate (**8h**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 30:1); Yield: 113.2 mg, 77%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.47-7.43 (m, 2H), 7.22-7.20 (m, 2H), 4.53-4.46 (m, 1H), 4.10-4.05 (m, 5H), 3.82-3.75 (m, 1H), 2.93-2.73 (m, 2H), 1.28-1.24 (m, 6H), 1.18 (t,  $J = 7.1$  Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.4 (t,  $J = 32.2$  Hz), 139.6 (d,  $J = 3.9$  Hz), 131.9, 129.7, 122.2, 114.4 (t,  $J = 252.0$  Hz), 64.4 (d,  $J = 6.1$  Hz), 64.3 (d,  $J = 5.7$  Hz), 63.4, 46.0-45.8 (m), 42.1 (td,  $J = 23.7, 7.5$  Hz), 15.8 (d,  $J = 8.5$  Hz), 15.7 (d,  $J = 8.5$  Hz), 14.0.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  89.40.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.84 (d,  $J = 265.2$  Hz), -104.74 (d,  $J = 265.3$  Hz). HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{16}\text{H}_{22}\text{BrF}_2\text{NaO}_4\text{PS}_2^+$ : 512.9741, found: 512.9736.

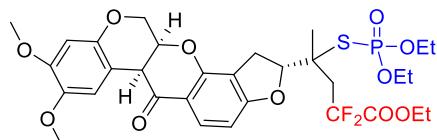
#### *O,O*-diethyl S-(3,3,4,4,5,5,6,6,6-nonafluoro-1-phenylhexyl) phosphorodithioate (**8i**)



Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 30:1); Yield: 61.0 mg, 40%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.35-7.26 (m, 5H), 4.71-4.64 (m, 1H), 4.16-3.99 (m, 3H), 3.88-3.81 (m, 1H), 3.03-2.76 (m, 2H), 1.28 (t,  $J = 7.1$  Hz, 3H), 1.22 (t,  $J = 7.1$

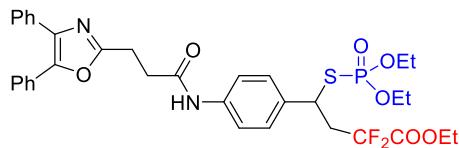
Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  140.6 (d,  $J = 4.9$  Hz), 129.1, 128.4, 127.6, 64.4 (d,  $J = 6.2$  Hz), 64.3 (d,  $J = 5.8$  Hz), 45.6-45.4 (m), 38.5 (td,  $J = 20.7, 6.0$  Hz), 15.84 (d,  $J = 3.4$  Hz), 15.75 (d,  $J = 3.4$  Hz).  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  89.48.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -81.02 – -81.12 (m, 3F), -112.12 (dt,  $J = 272.0, 13.0$  Hz, 1F), -114.18 (dt,  $J = 272.0, 11.3$  Hz, 1F), -124.45 – -124.57 (m, 2F), -125.90 – -126.02 (m, 2F). HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{16}\text{H}_{18}\text{F}_9\text{NaO}_2\text{PS}_2^+$ : 531.0234, found: 531.0224.

Ethyl 4-((diethoxyphosphoryl)thio)-4-((2R,6aS,12aS)-8,9-dimethoxy-6-oxo-1,2,6,6a,12,12a-hexahydrochromeno[3,4-*b*]furo[2,3-*h*]chromen-2-yl)-2,2-difluoropentanoate (**9a**, dr = 1.25:1)



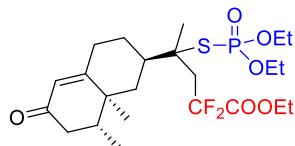
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 86.4 mg, 42%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.79 (dd,  $J = 8.6, 3.0$  Hz, 1H), 6.70 (d,  $J = 3.1$  Hz, 1H), 6.47-6.39 (m, 2H), 5.29-5.16 (m, 1H), 4.93-4.91 (m, 1H), 4.60-4.56 (m, 1H), 4.32-4.25 (m, 2H), 4.19-4.06 (m, 5H), 3.81 (d,  $J = 3.9$  Hz, 1H), 3.76 (s, 3H), 3.71 (s, 3H), 3.33-3.21 (m, 2H), 3.10-2.82 (m, 2H), 1.71 (s, 1.4H), 1.52 (s, 1.6H), 1.34-1.28 (m, 9H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  189.07, 189.06, 166.8, 166.7, 163.89 (t,  $J = 32.2$  Hz), 163.86 (t,  $J = 32.2$  Hz), 157.84, 157.82, 149.6, 147.5, 143.9, 130.1, 115.6 (t,  $J = 252.1$  Hz), 115.5 (t,  $J = 252.1$  Hz), 113.7, 112.79, 112.76, 110.45, 110.42, 104.9, 104.77, 104.73, 104.71, 101.0, 89.3 (d,  $J = 5.5$  Hz), 89.1 (d,  $J = 4.5$  Hz), 72.37, 72.35, 66.3, 64.5 (d,  $J = 7.1$  Hz), 64.4 (d,  $J = 7.5$  Hz), 64.37 (d,  $J = 4.8$  Hz), 64.32 (d,  $J = 4.5$  Hz), 63.4, 63.3, 56.4, 55.9, 55.7, 54.8, 44.6, 41.5 (t,  $J = 22.1$  Hz), 40.8 (t,  $J = 24.2$  Hz), 29.0, 28.4, 23.3, 21.0, 16.2 (d,  $J = 2.6$  Hz), 16.1 (d,  $J = 2.6$  Hz), 16.06 (d,  $J = 2.2$  Hz), 16.02 (d,  $J = 2.3$  Hz), 13.96, 13.95.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  22.48, 22.01.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -100.04 (d,  $J = 263.6$  Hz), -100.05 (d,  $J = 263.6$  Hz), -101.00 (d,  $J = 263.6$  Hz), -101.46 (d,  $J = 262.9$  Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{31}\text{H}_{38}\text{F}_2\text{O}_{11}\text{PS}^+$ : 687.1835, found: 687.1844.

Ethyl 4-((diethoxyphosphoryl)thio)-4-(4-(3-(4,5-diphenyloxazol-2-yl)propanamido)phenyl)-2,2-difluorobutanoate (**9b**)



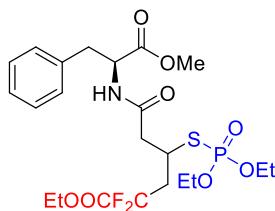
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 135.8 mg, 66%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  9.19 (s, 1H), 7.61-7.59 (m, 2H), 7.55-7.46 (m, 4H), 7.38-7.25 (m, 6H), 7.21 (d,  $J = 7.8$  Hz, 2H), 4.55-4.40 (m, 1H), 4.08-3.93 (m, 5H), 3.86-3.76 (m, 1H), 3.23 (t,  $J = 6.73$  Hz, 2H), 2.97-2.76 (m, 4H), 1.23-1.12 (m, 9H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  170.1, 163.3 (t,  $J = 32.4$  Hz), 162.6, 145.7, 138.5, 135.6 (d,  $J = 3.3$  Hz), 134.9, 132.3, 128.8 (2C, overlap), 128.7 (2C, overlap), 128.4, 128.3, 128.0, 126.5, 119.8, 114.4 (t,  $J = 252.1$  Hz), 64.0 (d,  $J = 6.1$  Hz), 63.9 (d,  $J = 5.8$  Hz), 63.2, 43.7, 42.4 (td,  $J = 23.6, 7.4$  Hz), 33.9, 24.0, 15.9 (d,  $J = 5.4$  Hz), 15.9 (d,  $J = 5.1$  Hz), 13.8.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  23.87.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.71 (d,  $J = 265.3$  Hz), -105.17 (d,  $J = 265.3$  Hz). HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{34}\text{H}_{37}\text{F}_2\text{N}_2\text{NaO}_7\text{PS}^+$ : 709.1919, found: 709.1924.

Ethyl 4-((diethoxyphosphoryl)thio)-4-((2R,8R,8aS)-8,8a-dimethyl-6-oxo-1,2,3,4,6,7,8,8a-octahydronaphthalen-2-yl)-2,2-difluoropentanoate (**9c**, dr = 1:1)



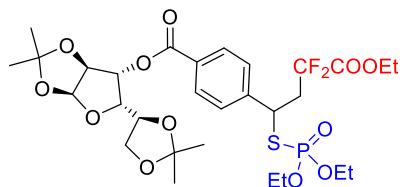
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 102.5 mg, 67%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  5.69 (s, 1H), 4.34 - 4.22 (m, 2H), 4.15-4.01 (m, 4H), 3.06-2.69 (m, 2H), 2.50-2.26 (m, 3H), 2.23-1.90 (m, 5H), 1.68 (d,  $J$  = 8.7 Hz, 3H), 1.35-1.25 (m, 10H), 1.19-1.08 (m, 1H), 1.04 (s, 3H), 0.96-0.91 (m, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  199.5, 199.4, 169.7, 169.6, 164.1 (t,  $J$  = 32.5 Hz), 164.0 (t,  $J$  = 32.5 Hz), 124.62, 124.55, 1115.81 (t,  $J$  = 252.6 Hz), 115.80 (t,  $J$  = 252.6 Hz), 64.01 (d,  $J$  = 7.0 Hz), 64.0 (d,  $J$  = 7.0 Hz), 63.3, 57.5 (d,  $J$  = 4.6 Hz), 57.2 (d,  $J$  = 4.5 Hz), 42.4-42.1 (m), 42.0, 40.5, 39.7, 39.52, 39.47, 32.75, 32.73, 28.16, 27.96, 26.6-26.4 (m), 26.3-26.1 (m), 16.9, 16.6, 16.15 (d,  $J$  = 2.7 Hz), 16.13 (d,  $J$  = 2.8 Hz), 16.08 (d,  $J$  = 2.8 Hz), 16.05 (d,  $J$  = 2.8 Hz), 15.11, 15.08, 13.9.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  23.44, 23.31.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -99.74 (d,  $J$  = 259.1 Hz), -100.33 (d,  $J$  = 259.2 Hz), -102.23 (d,  $J$  = 259.1 Hz), -103.40 (d,  $J$  = 258.7 Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{23}\text{H}_{38}\text{F}_2\text{O}_6\text{PS}^+$ : 511.2089, found: 511.2084.

Ethyl 4-((diethoxyphosphoryl)thio)-2,2-difluoro-6-((*S*)-1-methoxy-1-oxo-3-phenylpropan-2-yl)amino)-6-oxohexanoate (**9d**, dr = 1:1)



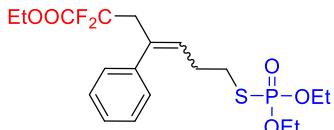
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 77.6 mg, 48%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.31-7.21 (m, 3H), 7.16-7.11 (m, 2H), 6.48 (s, 1H), 4.86 (dd,  $J$  = 13.2, 6.5 Hz, 1H), 4.33 (q,  $J$  = 7.1 Hz, 2H), 4.22-4.08 (m, 4H), 3.84-3.74 (m, 1H), 3.71 (s, 3H), 3.19 -3.03 (m, 2H), 2.87-2.63 (m, 4H), 1.38-1.32 (m, 9H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  171.9, 169.1 (d,  $J$  = 10.6 Hz), 163.6 (t,  $J$  = 32.3 Hz), 136.0 (d,  $J$  = 3.0 Hz), 129.3 (d,  $J$  = 2.3 Hz), 128.7, 127.2, 115.0 (t,  $J$  = 252.0 Hz), 64.3 (d,  $J$  = 6.7 Hz), 64.24 (d,  $J$  = 6.0 Hz), 64.20 (d,  $J$  = 6.2 Hz), 63.3, 53.4, 52.4, 42.5-42.3 (m), 39.8 (tt,  $J$  = 22.8, 4.7 Hz), 38.0 (d,  $J$  = 6.0 Hz), 36.6-36.5 (m), 16.1 (d,  $J$  = 7.3 Hz), 14.0.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  24.88.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -102.73 (d,  $J$  = 100.1 Hz), -103.29 (d,  $J$  = 100.0 Hz), -105.34 (d,  $J$  = 71.3 Hz), -105.90 (d,  $J$  = 71.3 Hz). HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{22}\text{H}_{33}\text{F}_2\text{NO}_8\text{PS}^+$ : 540.1627, found: 540.1634.

(3a*S*,5*S*,6*R*,6a*S*)-5-((*S*)-2,2-Dimethyl-1,3-dioxolan-4-yl)-2,2-dimethyltetrahydrofuro[2,3-*d*][1,3]dioxol-6-yl 4-(1-((diethoxyphosphoryl)thio)-4-ethoxy-3,3-difluoro-4-oxobutyl)benzoate (**9e**, dr = 1:1)



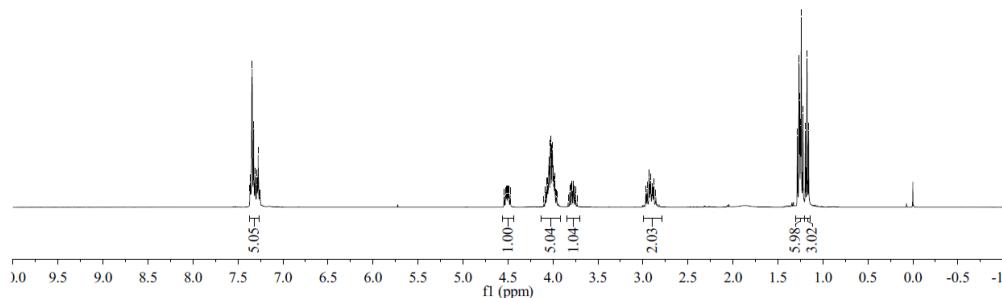
Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 92.1 mg, 45%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.96 (d,  $J$  = 7.6 Hz, 2H), 7.43 (d,  $J$  = 7.8 Hz, 2H), 5.91 (d,  $J$  = 2.8 Hz, 1H), 5.45 (s, 1H), 4.60-4.52 (m, 2H), 4.23-4.25 (m, 2H), 4.15-3.91 (m, 7H), 3.88-3.77 (m, 1H), 3.01-2.74 (m, 2H), 1.52 (s, 3H), 1.37 (s, 3H), 1.30-1.15 (m, 15H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  164.7, 163.3 (td,  $J$  = 32.3, 3.7 Hz), 146.6 (d,  $J$  = 3.7 Hz), 130.2, 129.3, 128.0, 114.3 (t,  $J$  = 252.0 Hz), 112.5, 109.5, 105.2, 83.5, 80.0, 76.9, 72.6, 67.4, 64.0 (d,  $J$  = 2.6 Hz), 63.97, 63.94 (d,  $J$  = 2.6 Hz), 43.5-43.3 (m), 42.0 (td,  $J$  = 23.0, 7.2 Hz), 27.0, 26.8, 26.3, 25.3, 16.0 (d,  $J$  = 7.4 Hz), 13.9.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  23.21.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -104.08. HRMS:  $[\text{M}+\text{Na}]^+$   $m/z$  calcd for  $\text{C}_{29}\text{H}_{41}\text{F}_2\text{NaO}_{12}\text{PS}^+$ : 705.1917, found: 705.1913.

#### Ethyl 7-((diethoxyphosphoryl)thio)-2,2-difluoro-4-phenylhept-4-enoate (**11**)

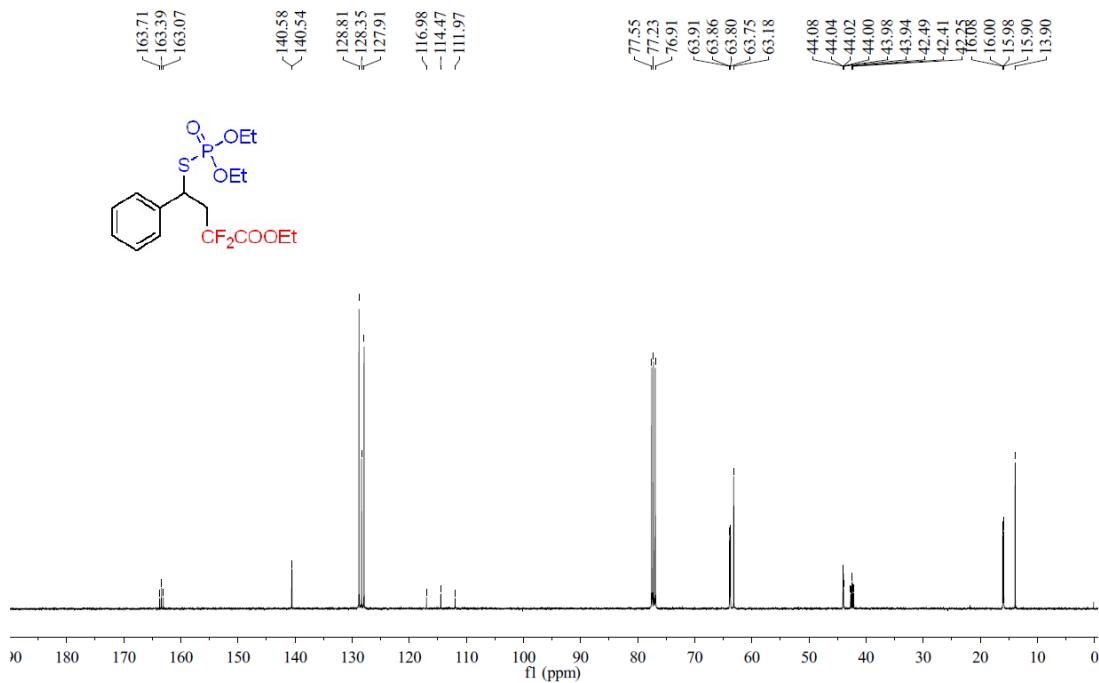
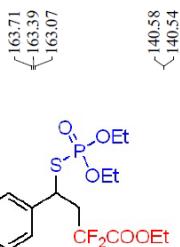


Purification by flash column chromatography (eluent/petroleum ether/EtOAc = 3:1); Yield: 39.2 mg, 30%; Colourless liquid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.39-7.21 (m, 5H), 5.89 (t,  $J$  = 7.3 Hz, 1H), 4.27-4.10 (m, 4H), 3.86 (q,  $J$  = 7.2 Hz, 2H), 3.36 (t,  $J$  = 15.7 Hz, 2H), 2.95 (dt,  $J$  = 14.8, 7.4 Hz, 2H), 2.66 (q,  $J$  = 7.4 Hz, 2H), 1.36 (t, 7.1 Hz, 6H), 1.13 (t,  $J$  = 7.2 Hz, 3H).  $^{13}\text{C}$  NMR (151 MHz,  $\text{CDCl}_3$ )  $\delta$  163.9 (t,  $J$  = 32.5 Hz), 142.8, 133.0, 128.5, 127.7, 127.0, 132.6 (t,  $J$  = 4.2 Hz), 115.2 (t,  $J$  = 252.0 Hz), 63.9 (d,  $J$  = 6.1 Hz), 63.0, 35.8 (t,  $J$  = 24.6 Hz), 30.7 (d,  $J$  = 5.2 Hz), 30.4 (d,  $J$  = 4.0 Hz), 16.2 (d,  $J$  = 7.3 Hz), 13.8.  $^{31}\text{P}$  NMR (243 MHz,  $\text{CDCl}_3$ )  $\delta$  27.89.  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3$ )  $\delta$  -103.27. HRMS:  $[\text{M}+\text{H}]^+$   $m/z$  calcd for  $\text{C}_{19}\text{H}_{28}\text{F}_2\text{O}_5\text{PS}^+$ : 437.1358, found: 437.1351.

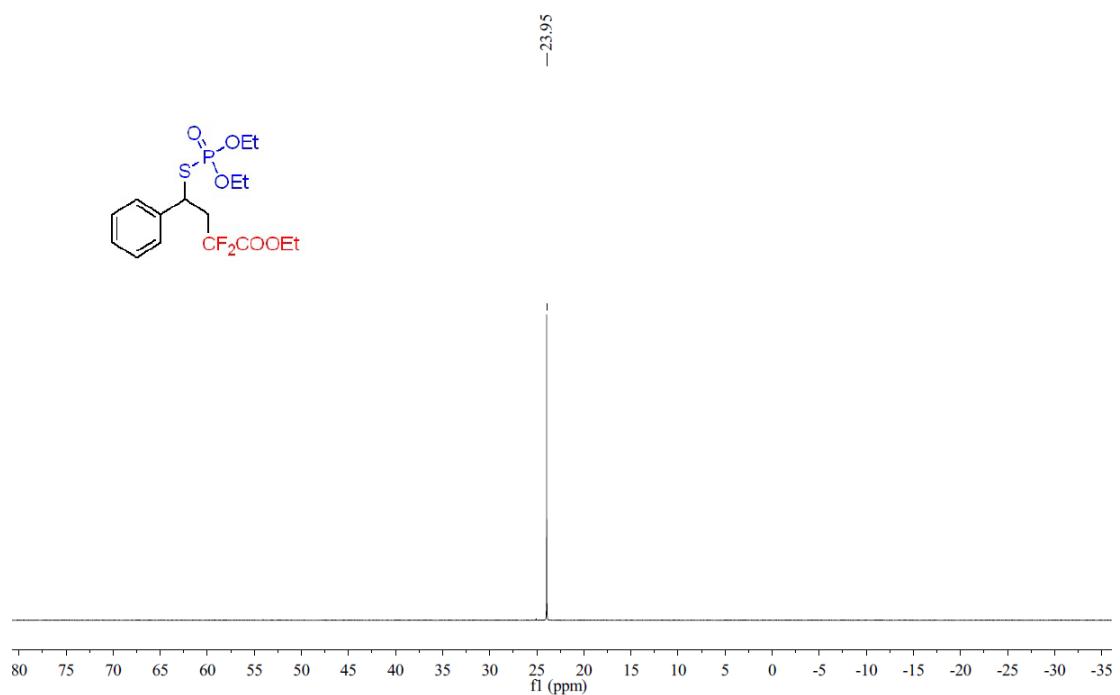
<sup>1</sup>H NMR (400 MHz) Spectrum of **4a** in CDCl<sub>3</sub>



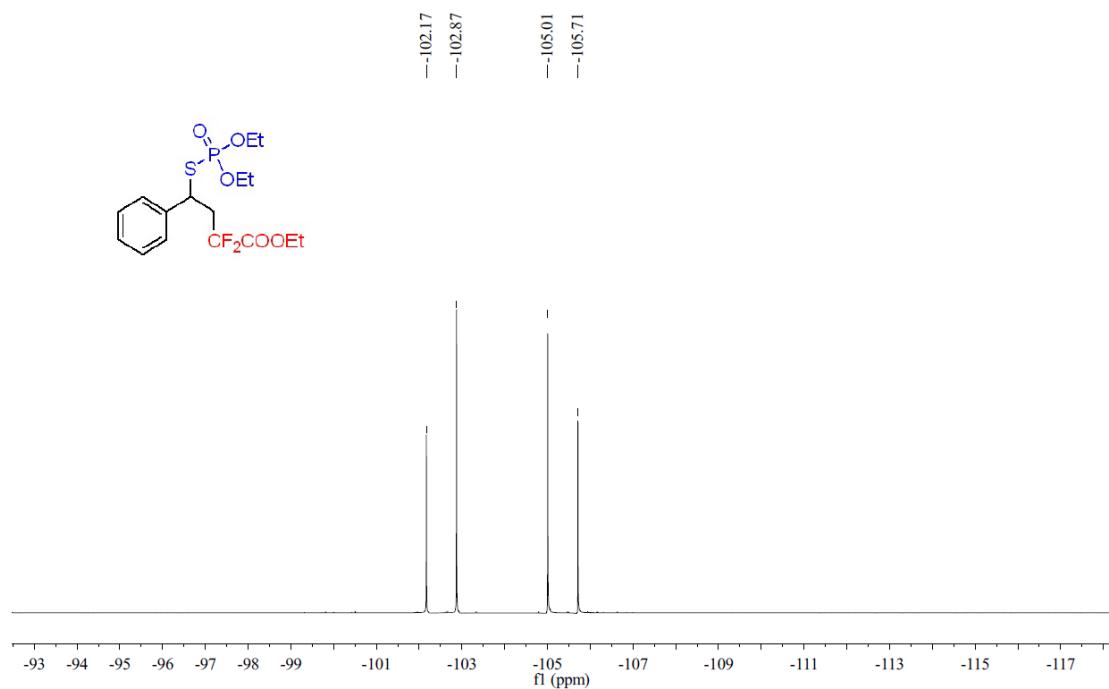
<sup>13</sup>C NMR (151 MHz) Spectrum of **4a** in CDCl<sub>3</sub>



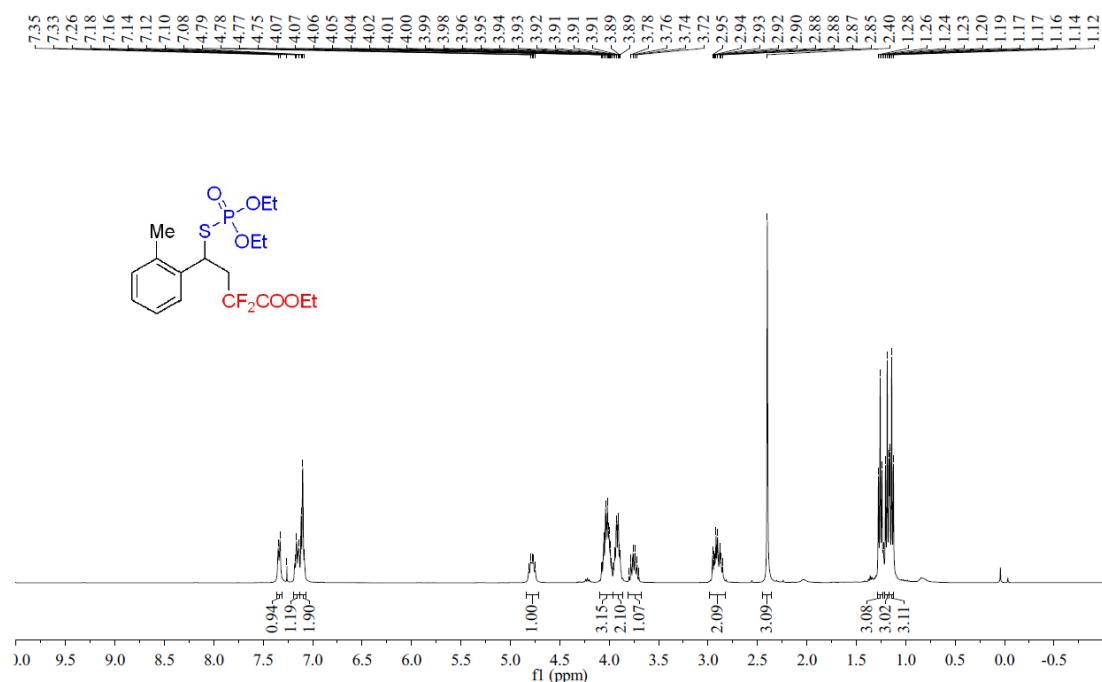
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4a** in  $\text{CDCl}_3$



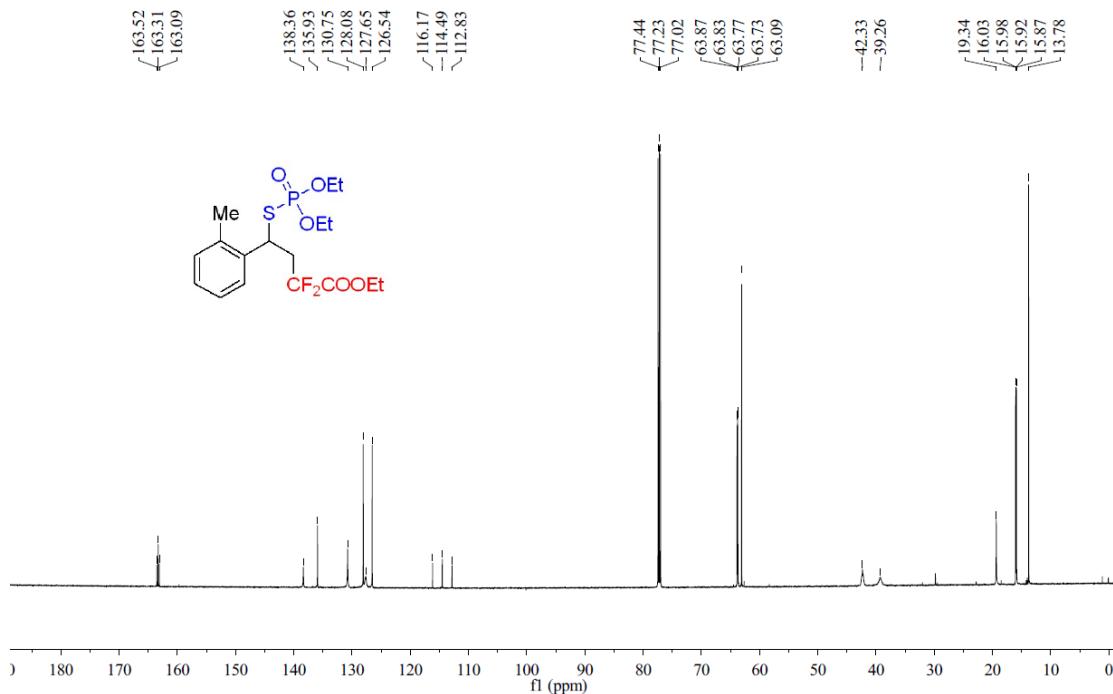
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4a** in  $\text{CDCl}_3$



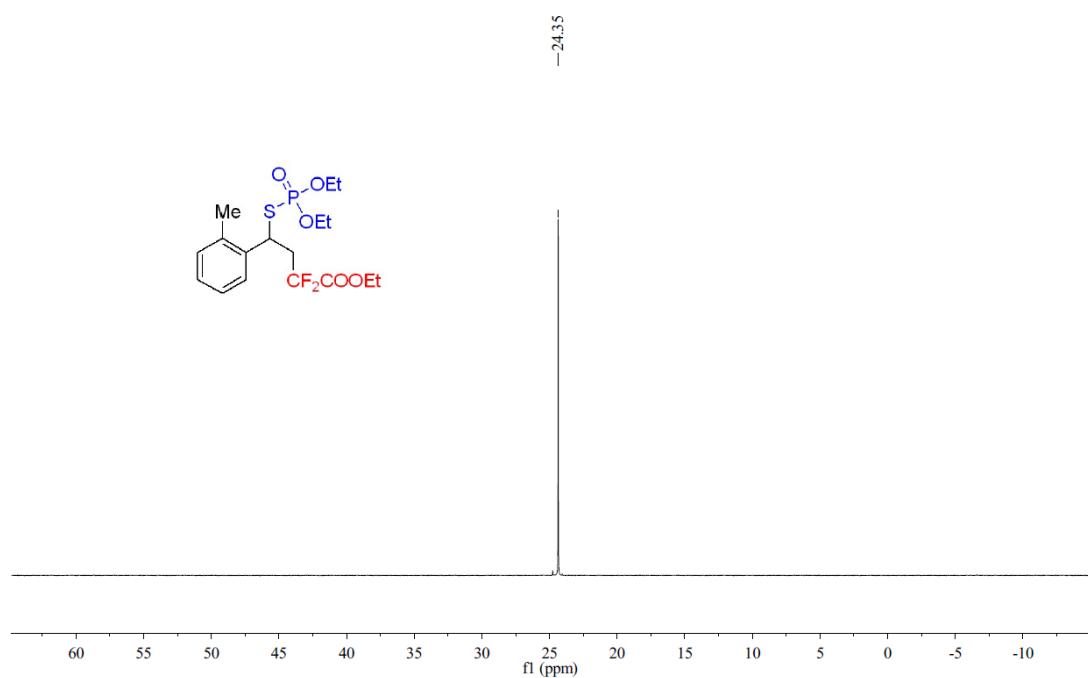
<sup>1</sup>H NMR (400 MHz) Spectrum of **4b** in CDCl<sub>3</sub>



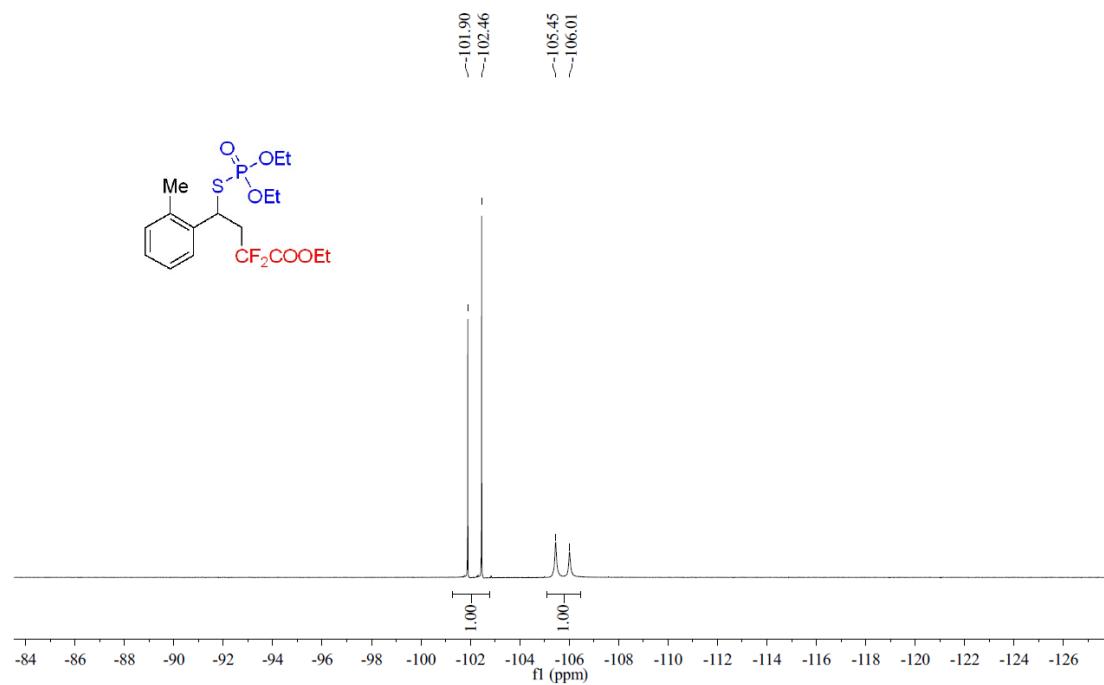
<sup>13</sup>C NMR (151 MHz) Spectrum of **4b** in CDCl<sub>3</sub>



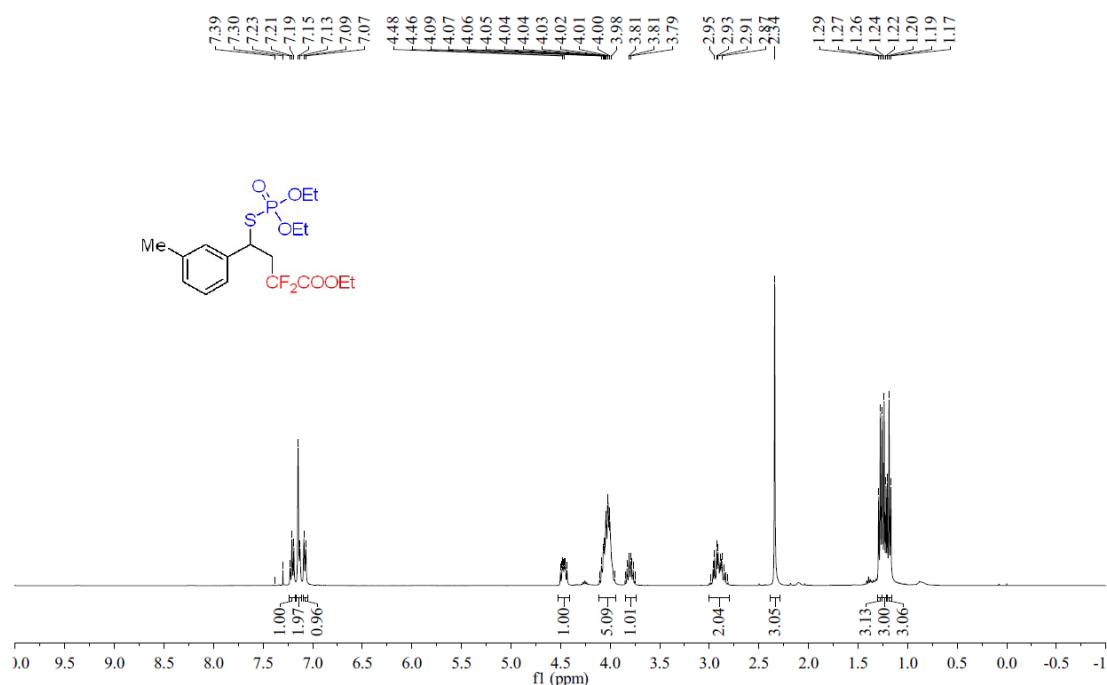
<sup>31</sup>P NMR (243 MHz) Spectrum of **4b** in CDCl<sub>3</sub>



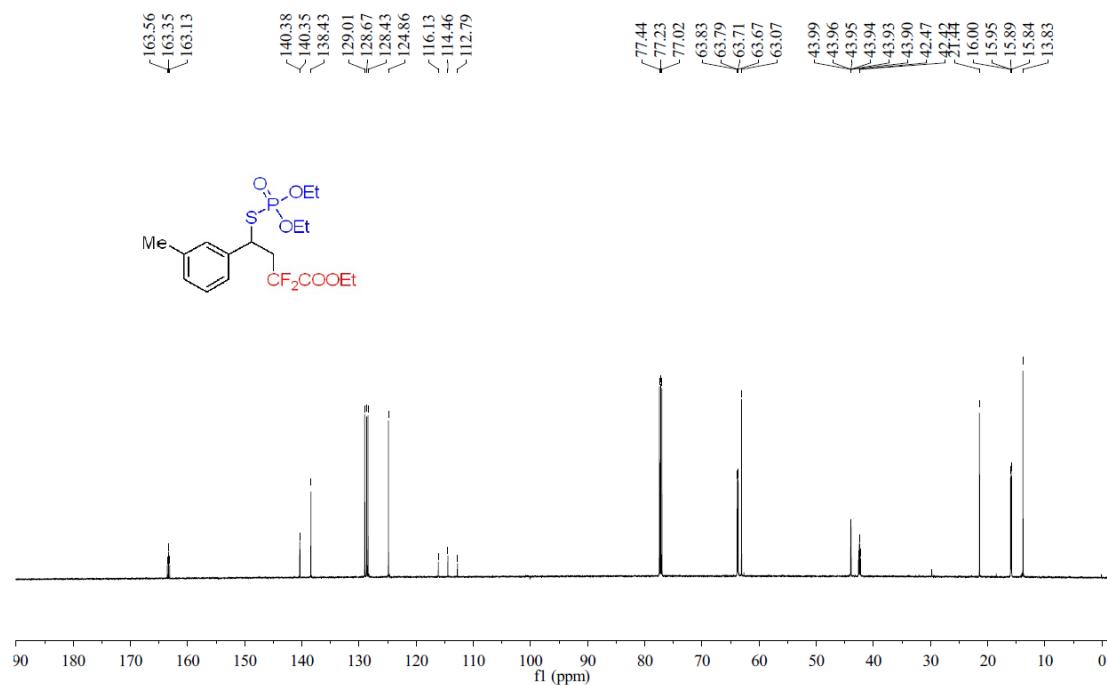
<sup>19</sup>F NMR (471 MHz) Spectrum of **4b** in CDCl<sub>3</sub>



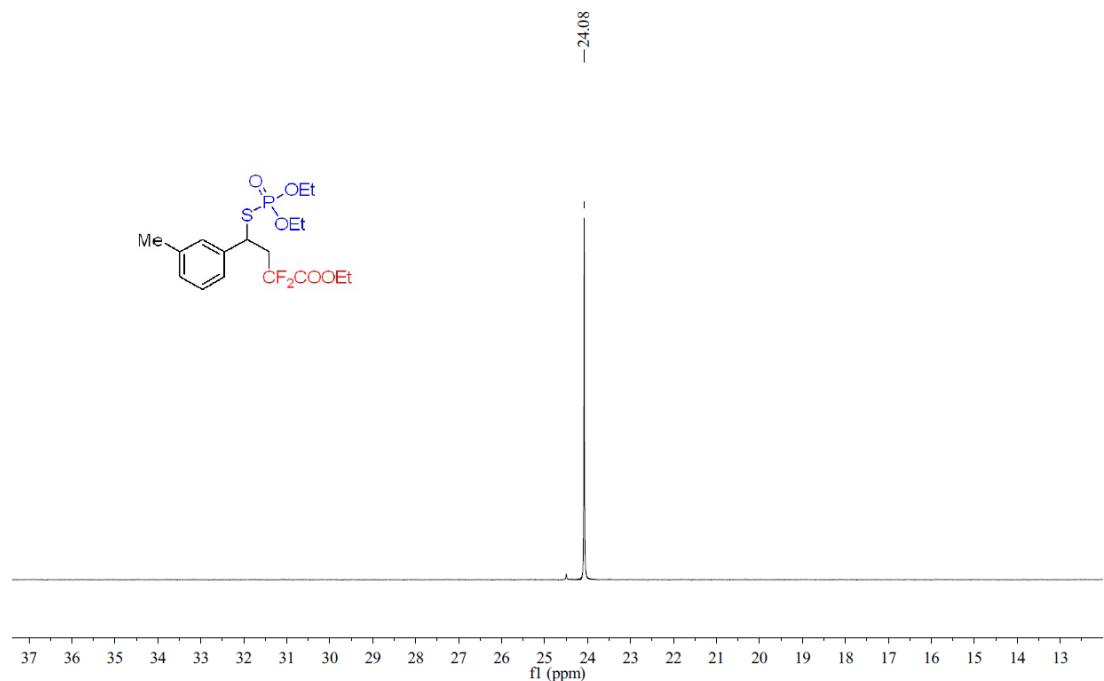
<sup>1</sup>H NMR (400 MHz) Spectrum of **4c** in CDCl<sub>3</sub>



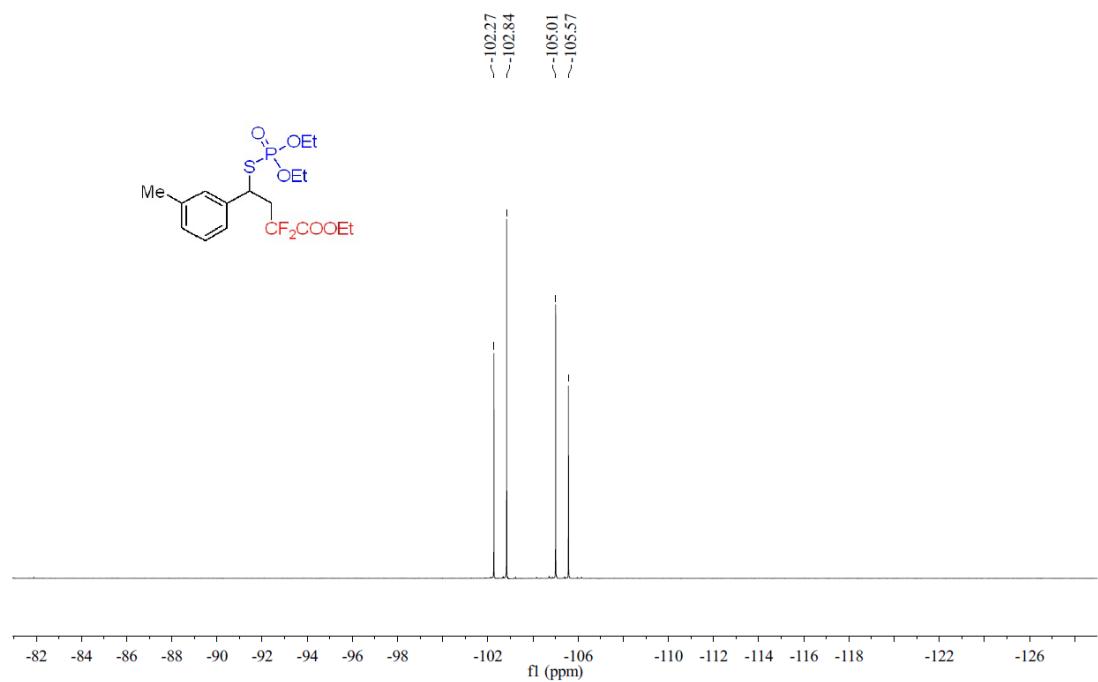
<sup>13</sup>C NMR (151 MHz) Spectrum of **4b** in CDCl<sub>3</sub>



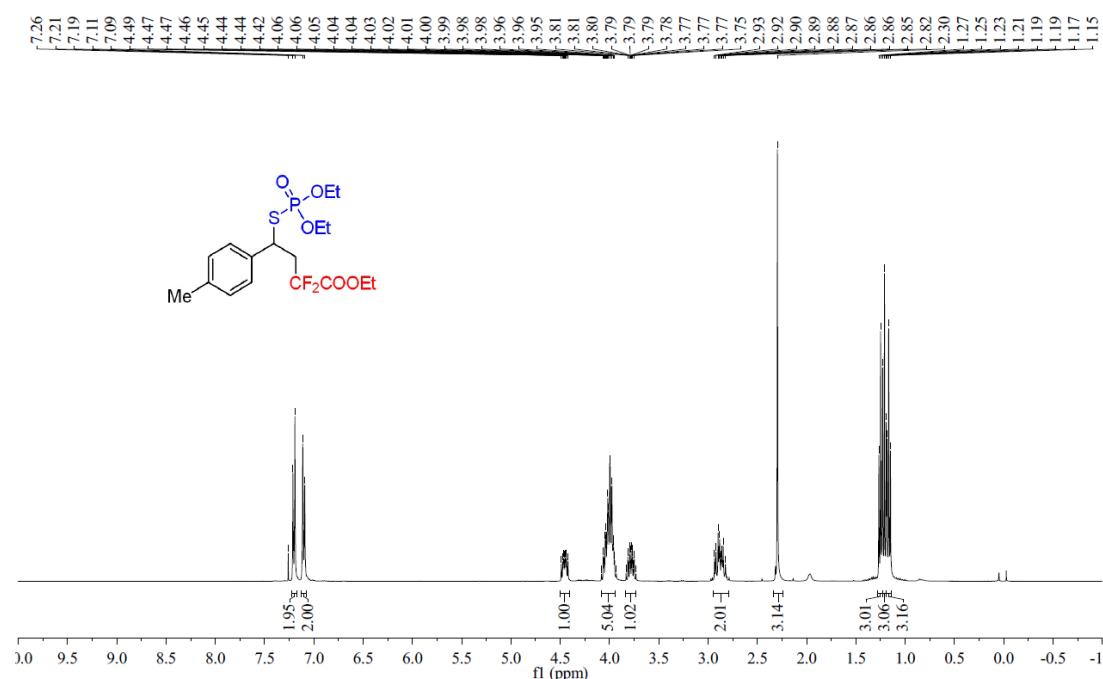
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4c** in  $\text{CDCl}_3$



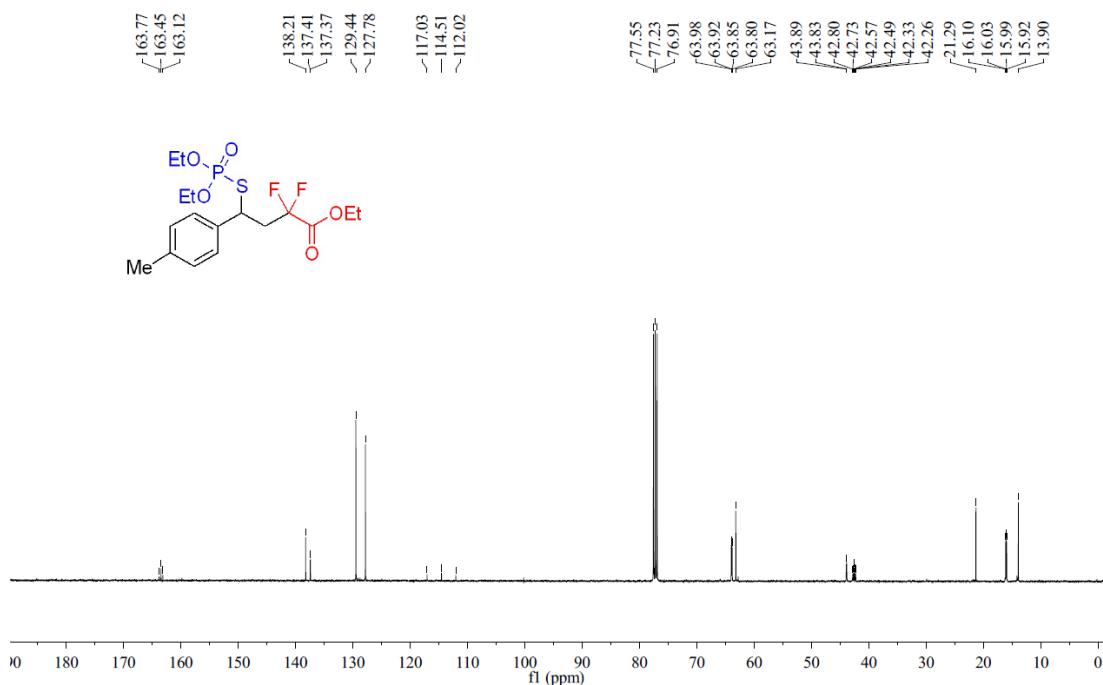
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4c** in  $\text{CDCl}_3$



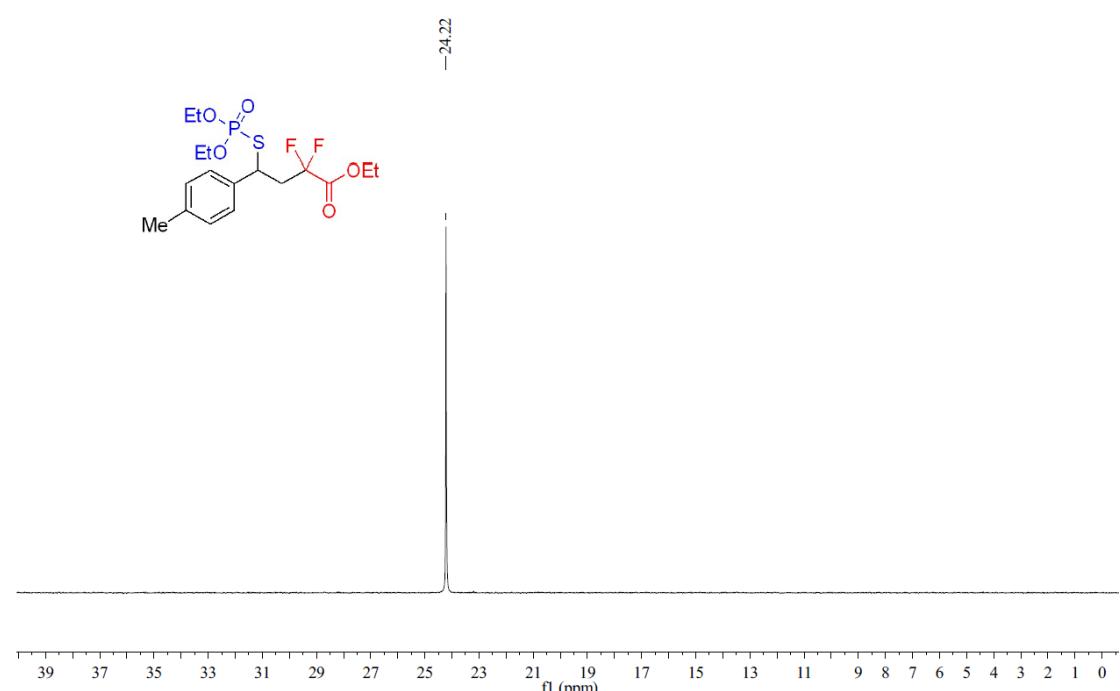
<sup>1</sup>H NMR (400 MHz) Spectrum of **4d** in CDCl<sub>3</sub>



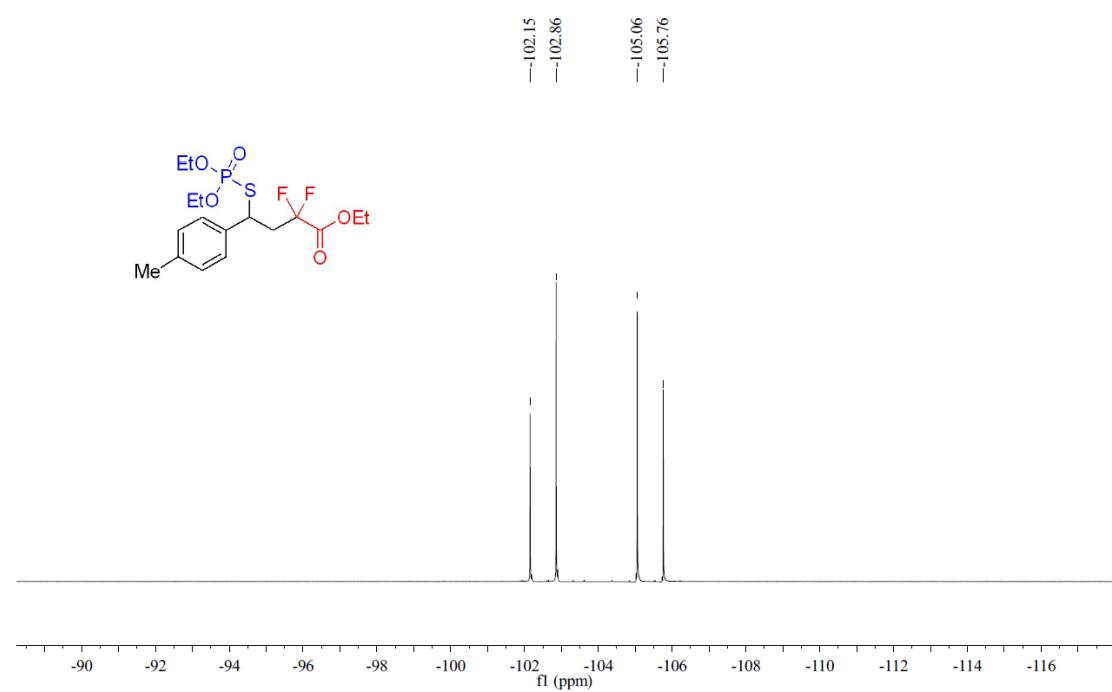
<sup>13</sup>C NMR (151 MHz) Spectrum of **4d** in CDCl<sub>3</sub>



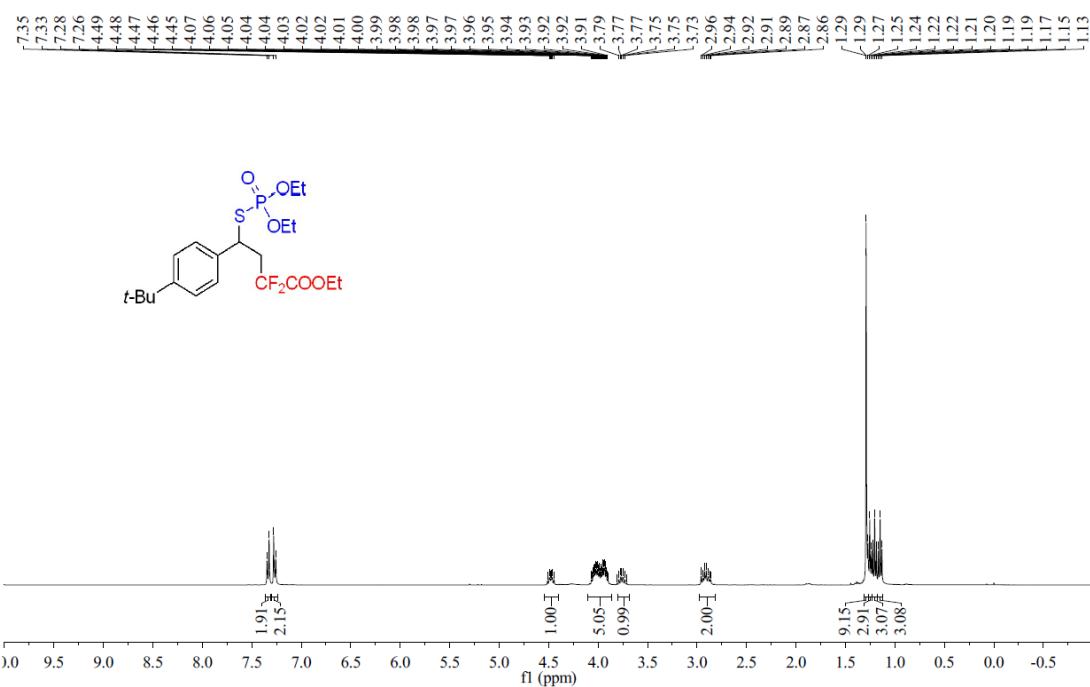
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4d** in  $\text{CDCl}_3$



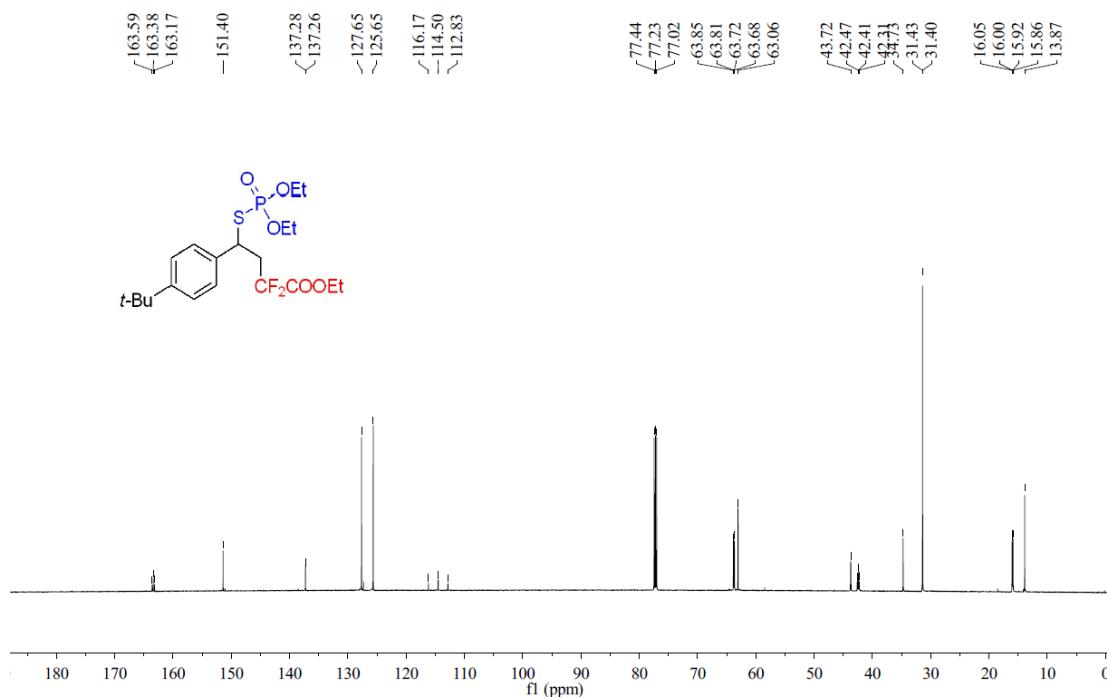
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4d** in  $\text{CDCl}_3$



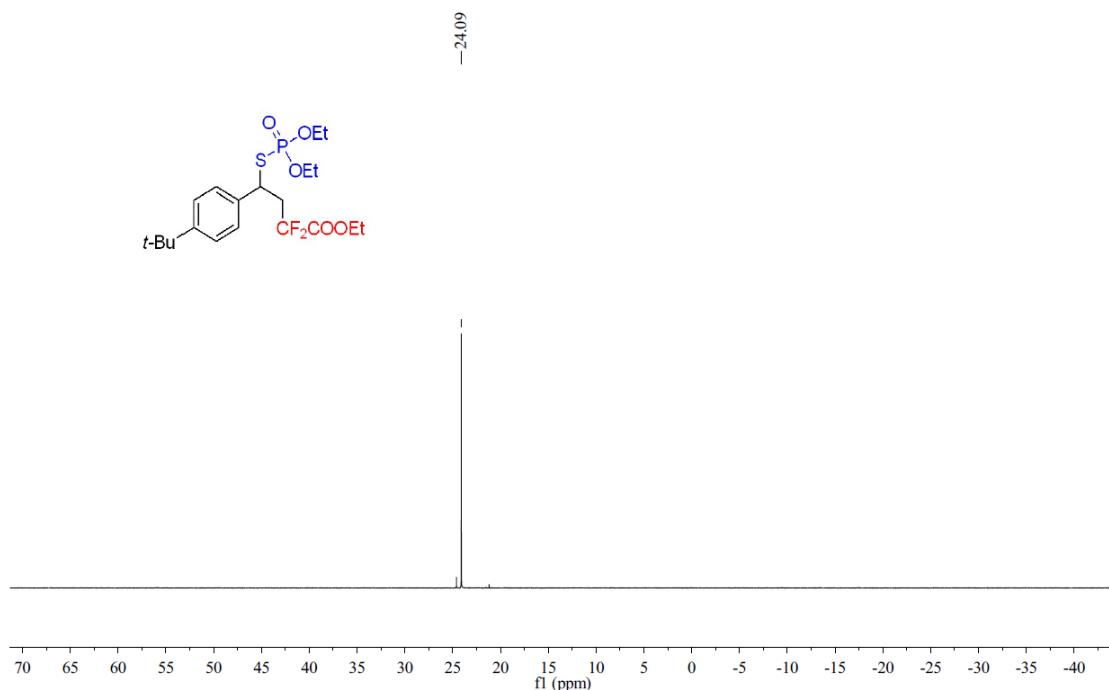
<sup>1</sup>H NMR (400 MHz) Spectrum of **4e** in CDCl<sub>3</sub>



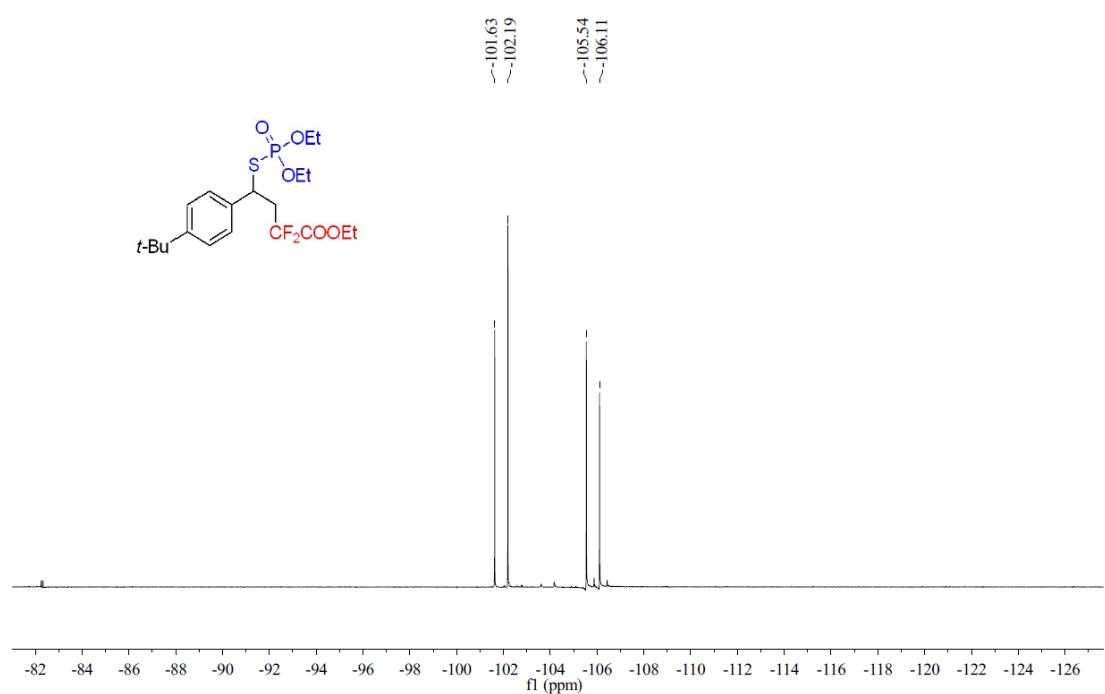
<sup>13</sup>C NMR (151 MHz) Spectrum of **4e** in CDCl<sub>3</sub>



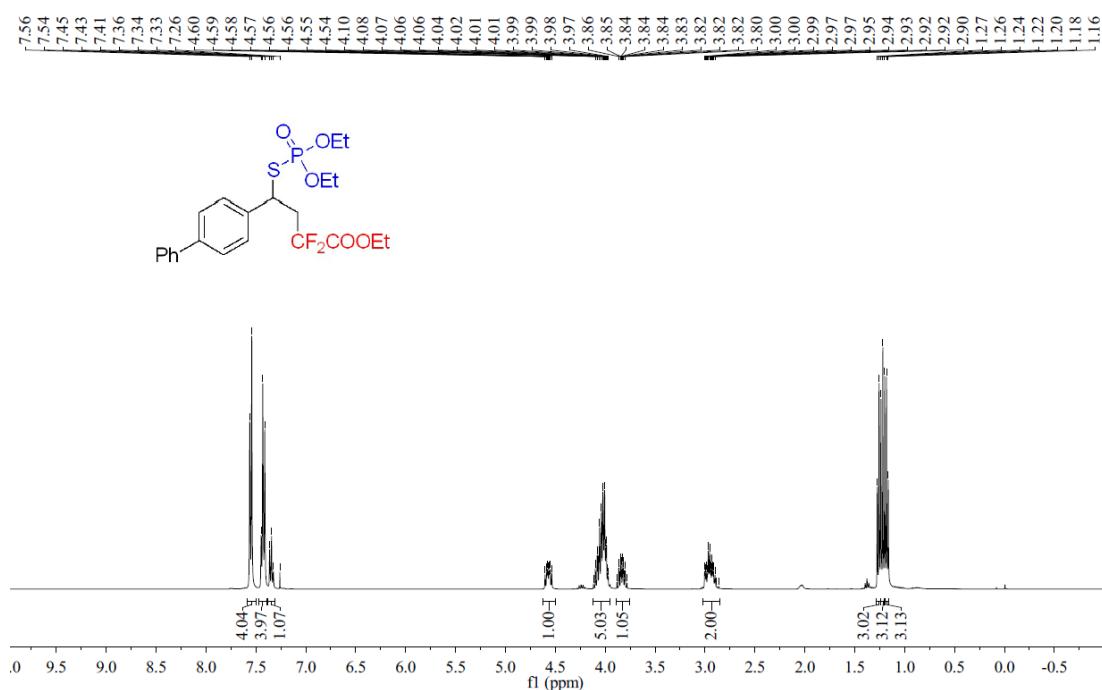
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4e** in  $\text{CDCl}_3$



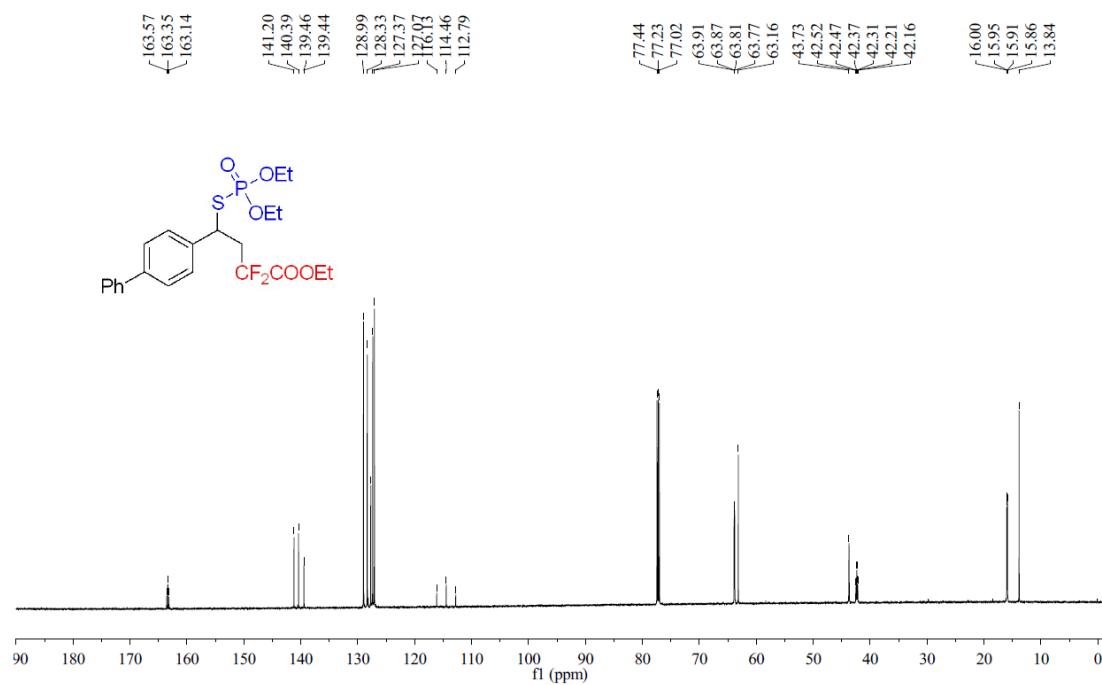
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4e** in  $\text{CDCl}_3$



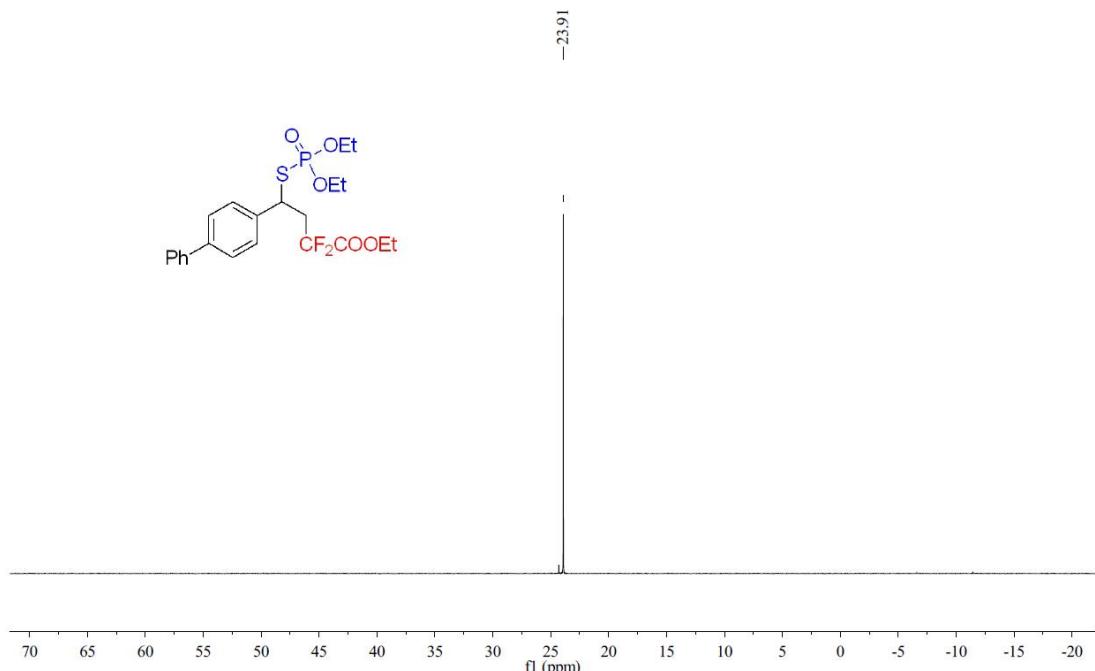
<sup>1</sup>H NMR (400 MHz) Spectrum of **4f** in CDCl<sub>3</sub>



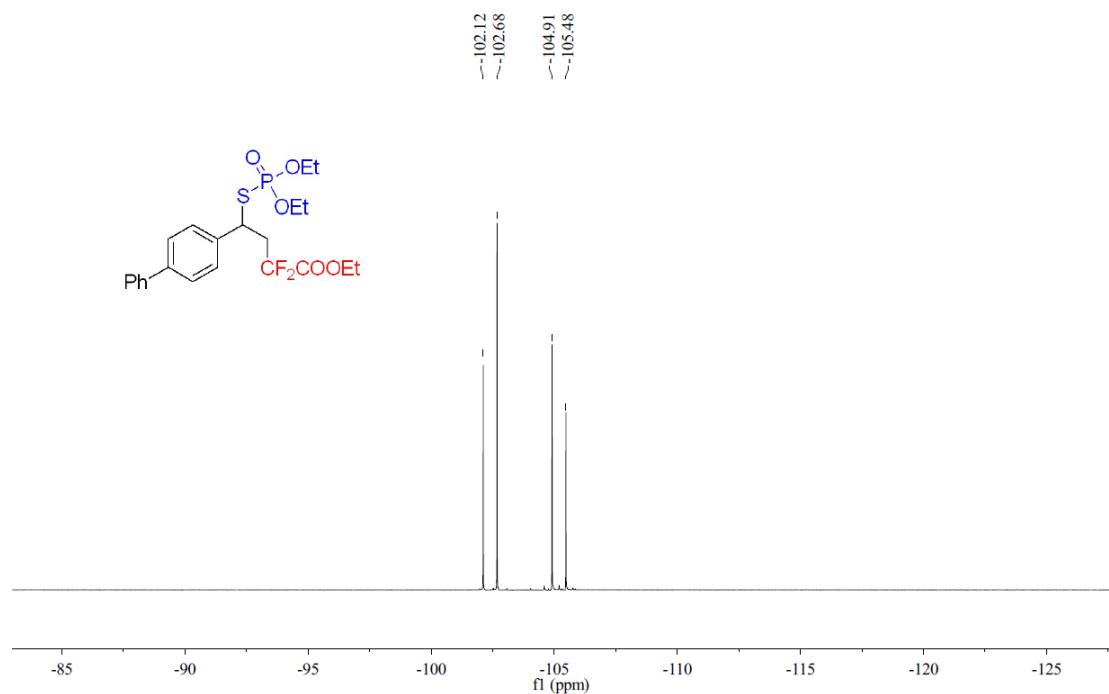
<sup>13</sup>C NMR (151 MHz) Spectrum of **4f** in CDCl<sub>3</sub>



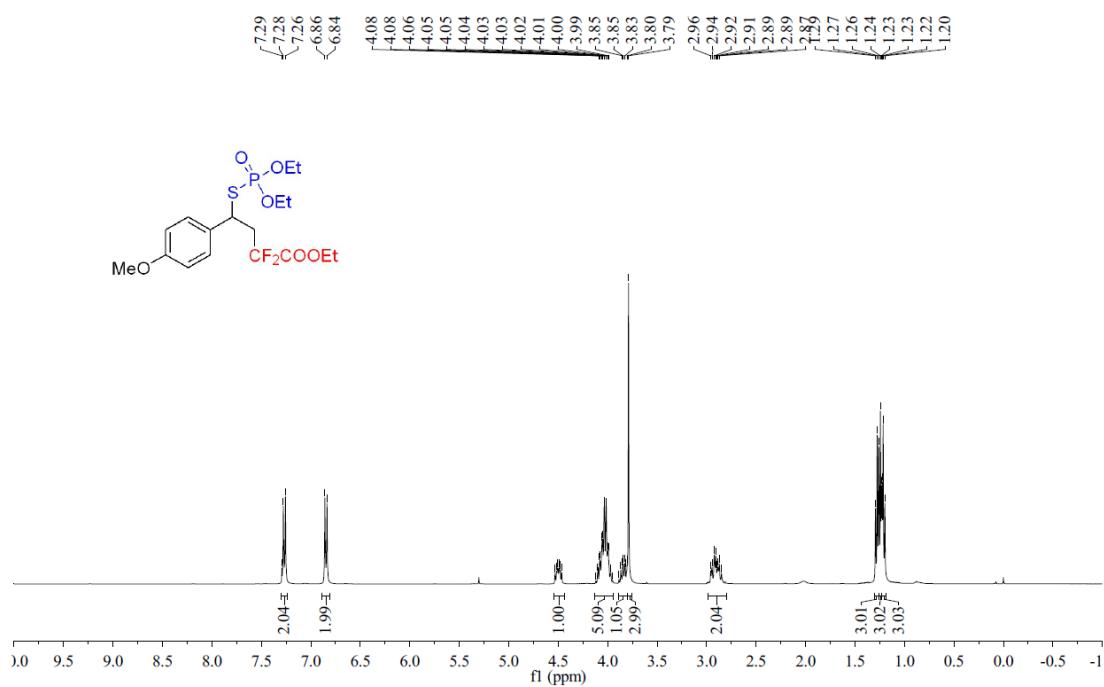
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4f** in  $\text{CDCl}_3$



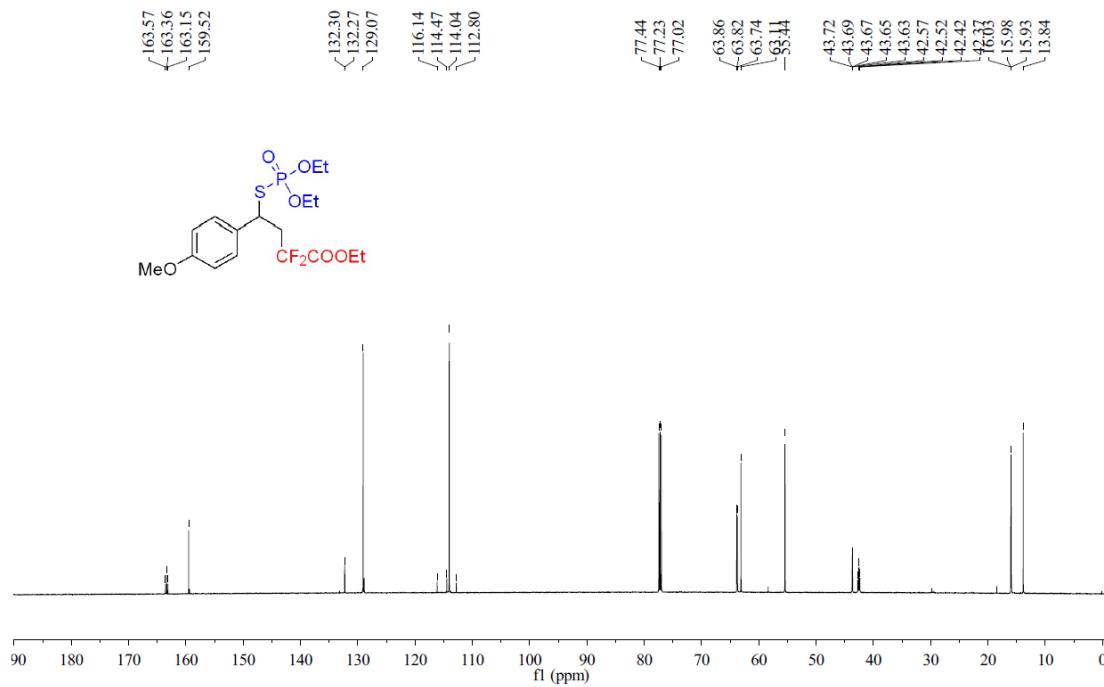
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4f** in  $\text{CDCl}_3$



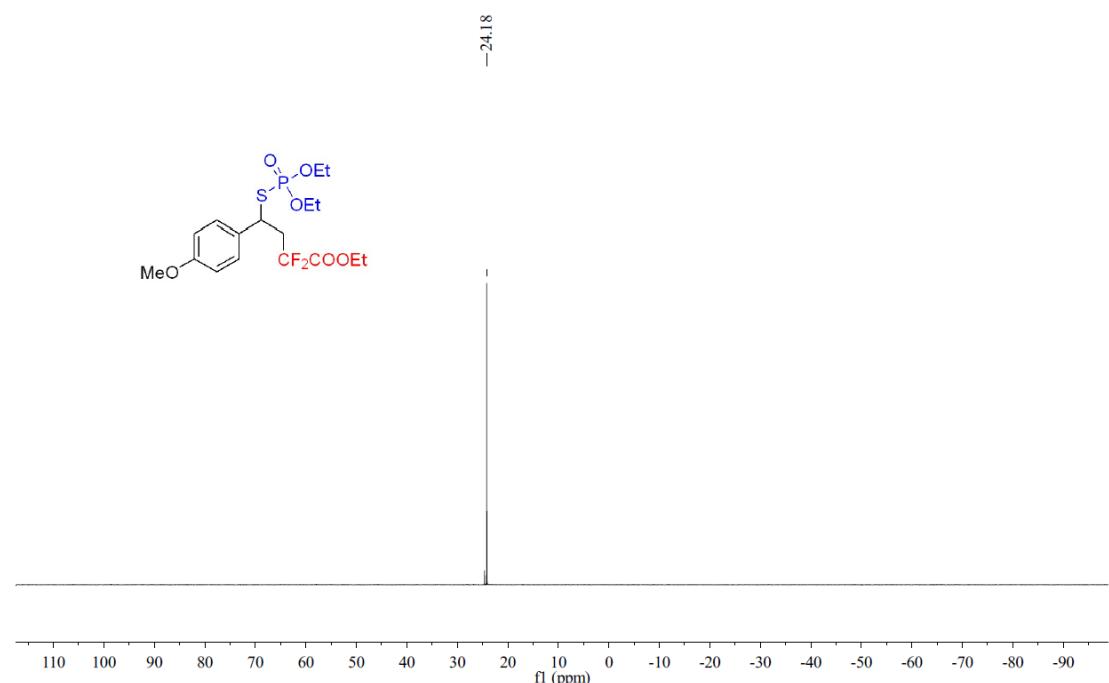
<sup>1</sup>H NMR (400 MHz) Spectrum of **4g** in CDCl<sub>3</sub>



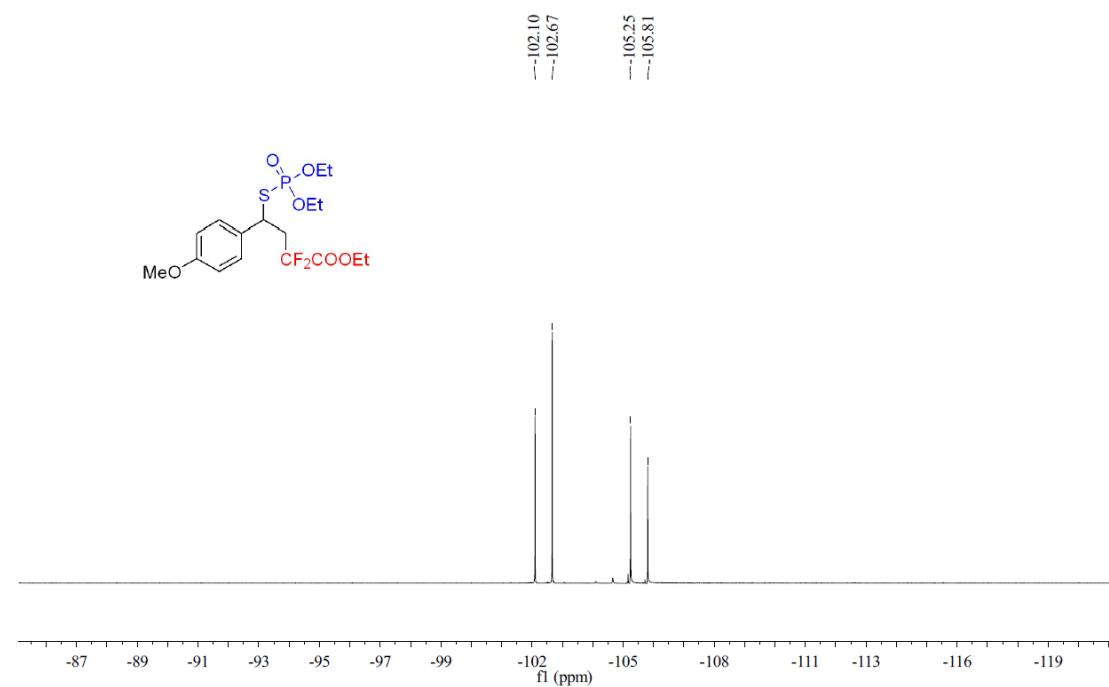
<sup>13</sup>C NMR (151 MHz) Spectrum of **4g** in CDCl<sub>3</sub>



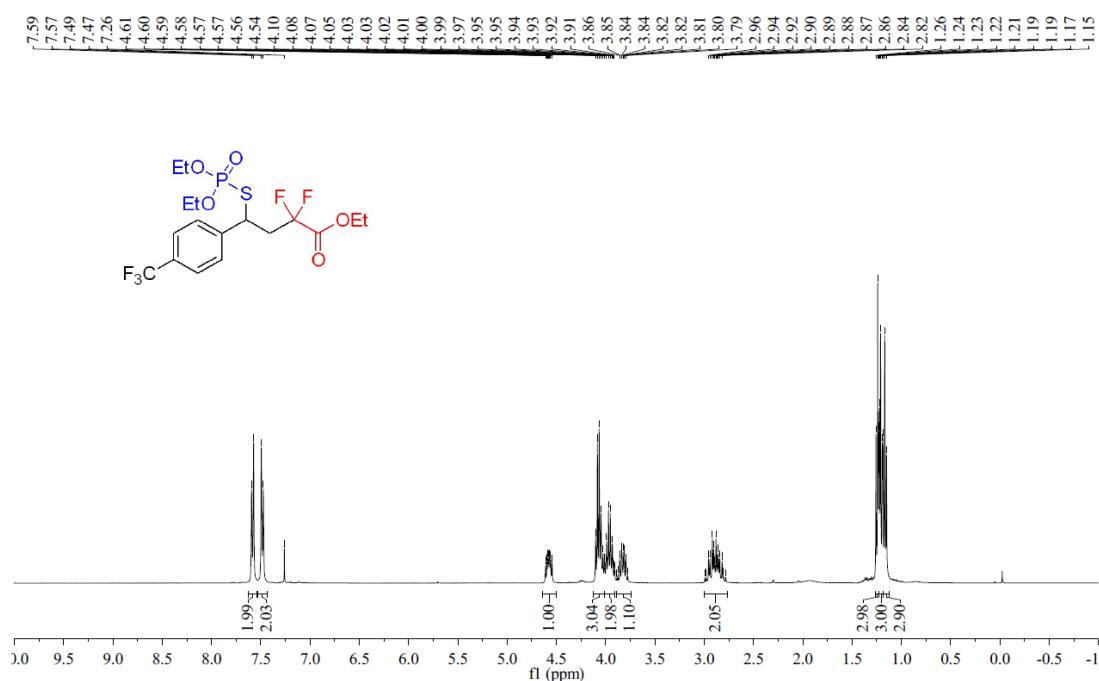
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4g** in  $\text{CDCl}_3$



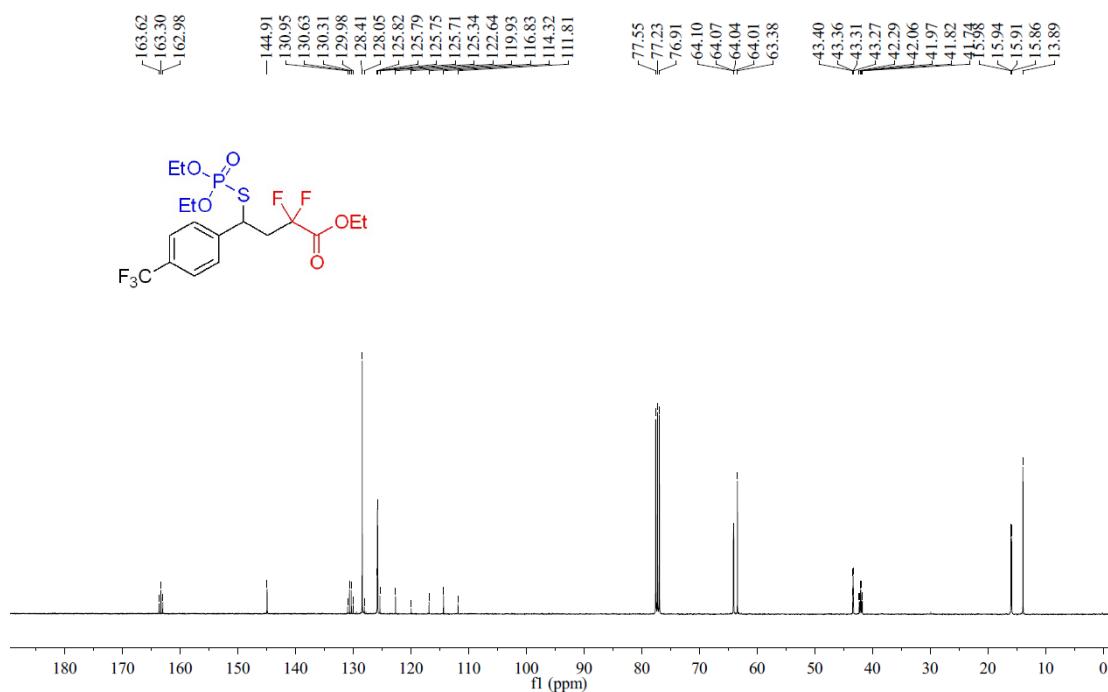
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4g** in  $\text{CDCl}_3$



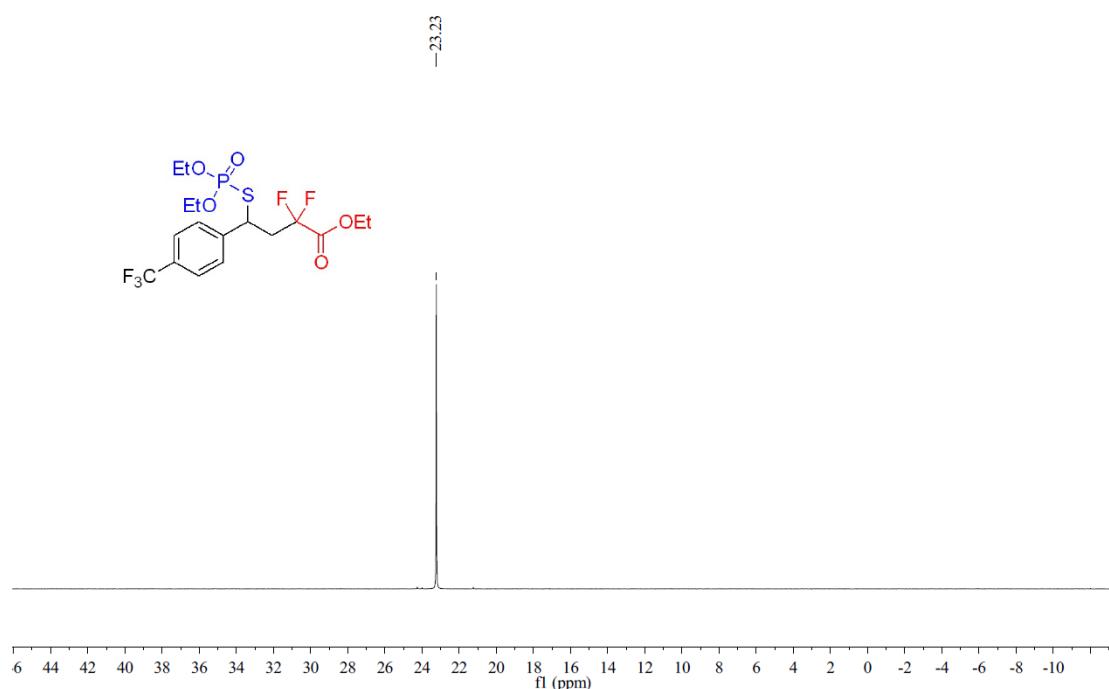
<sup>1</sup>H NMR (400 MHz) Spectrum of **4h** in CDCl<sub>3</sub>



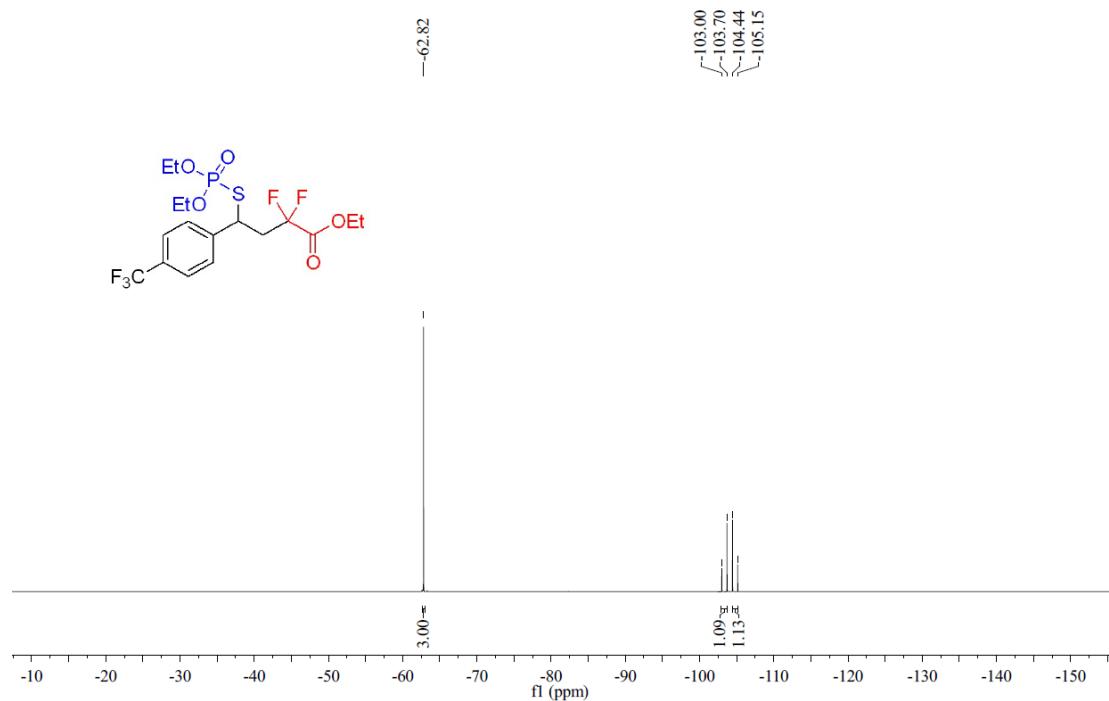
<sup>13</sup>C NMR (151 MHz) Spectrum of **4h** in CDCl<sub>3</sub>



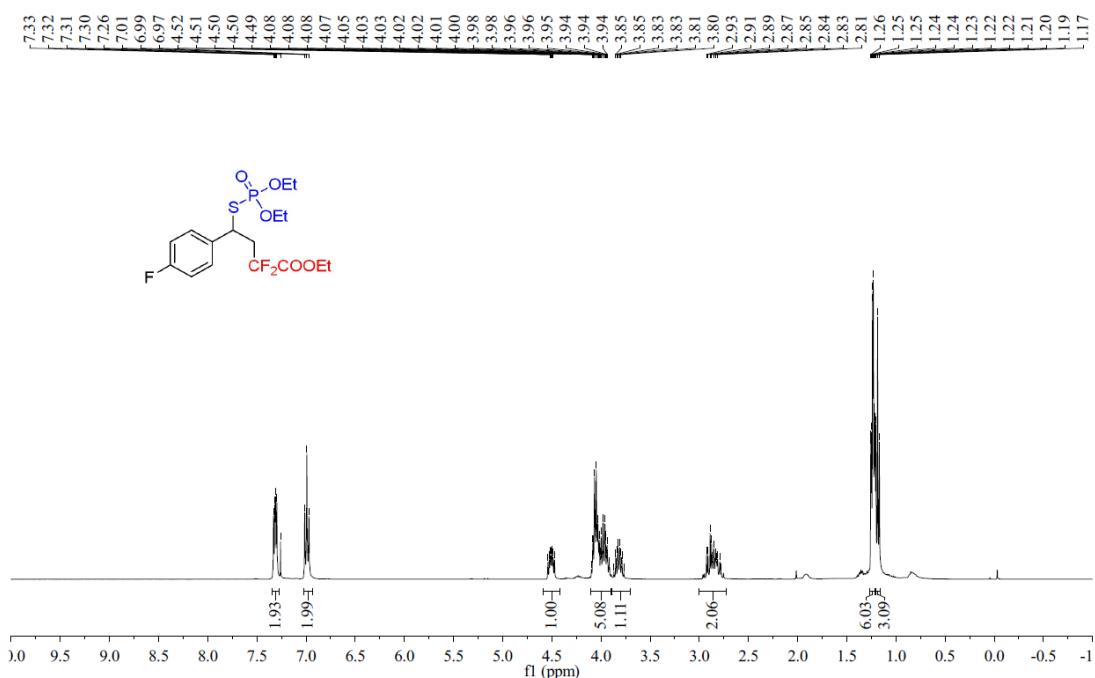
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4h** in  $\text{CDCl}_3$



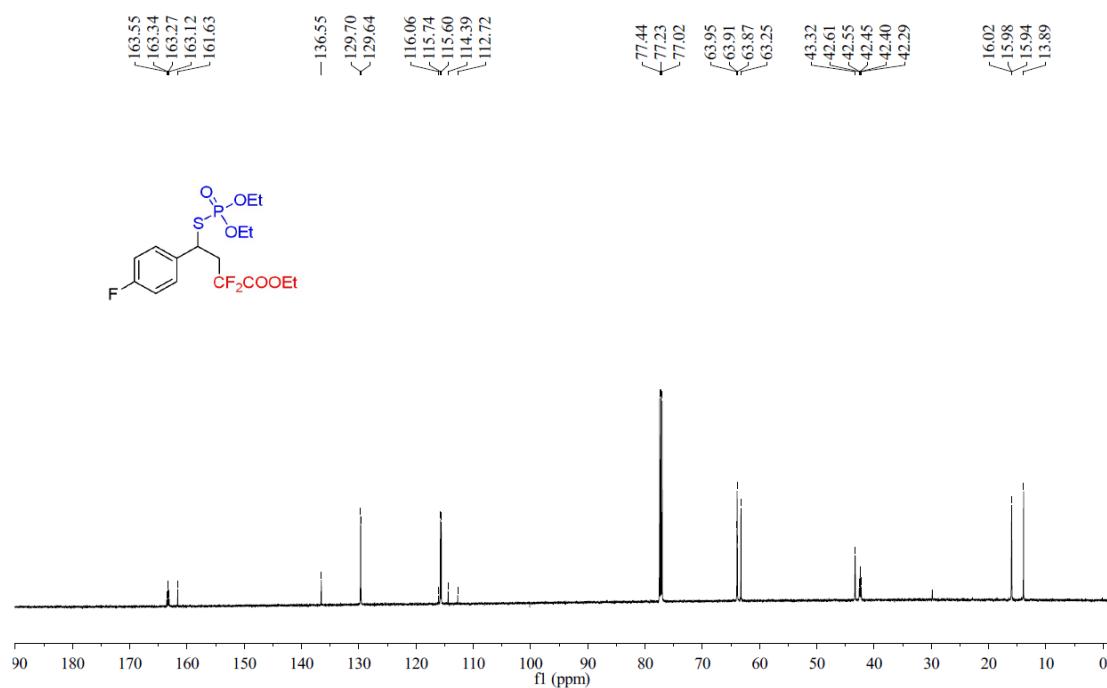
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4h** in  $\text{CDCl}_3$



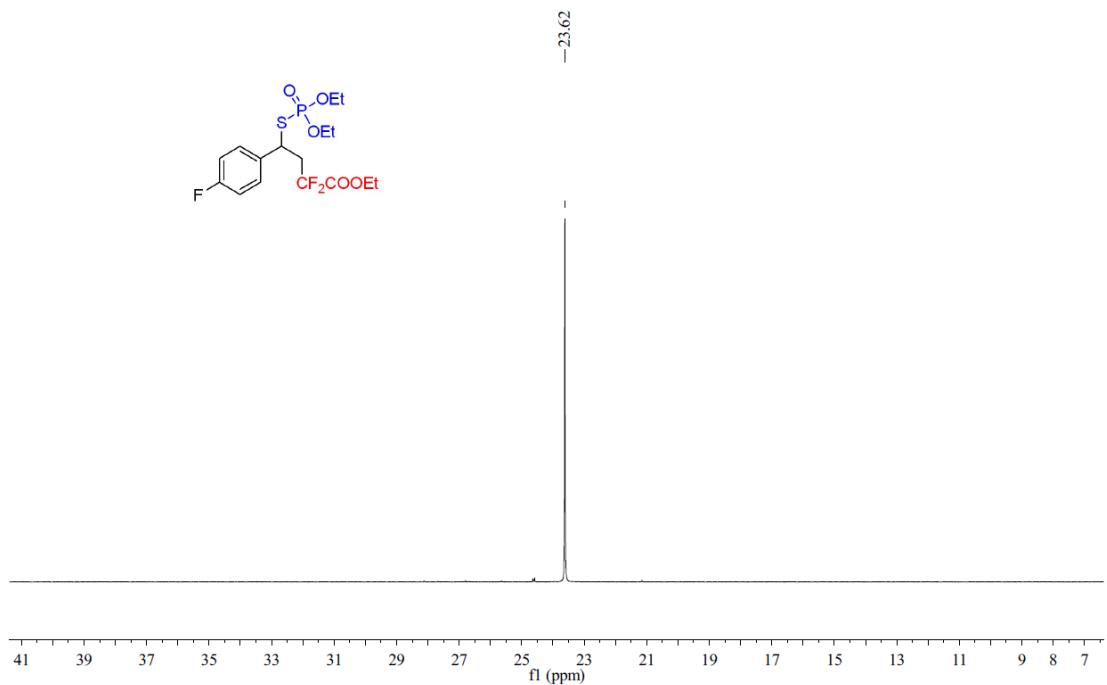
<sup>1</sup>H NMR (400 MHz) Spectrum of **4i** in CDCl<sub>3</sub>



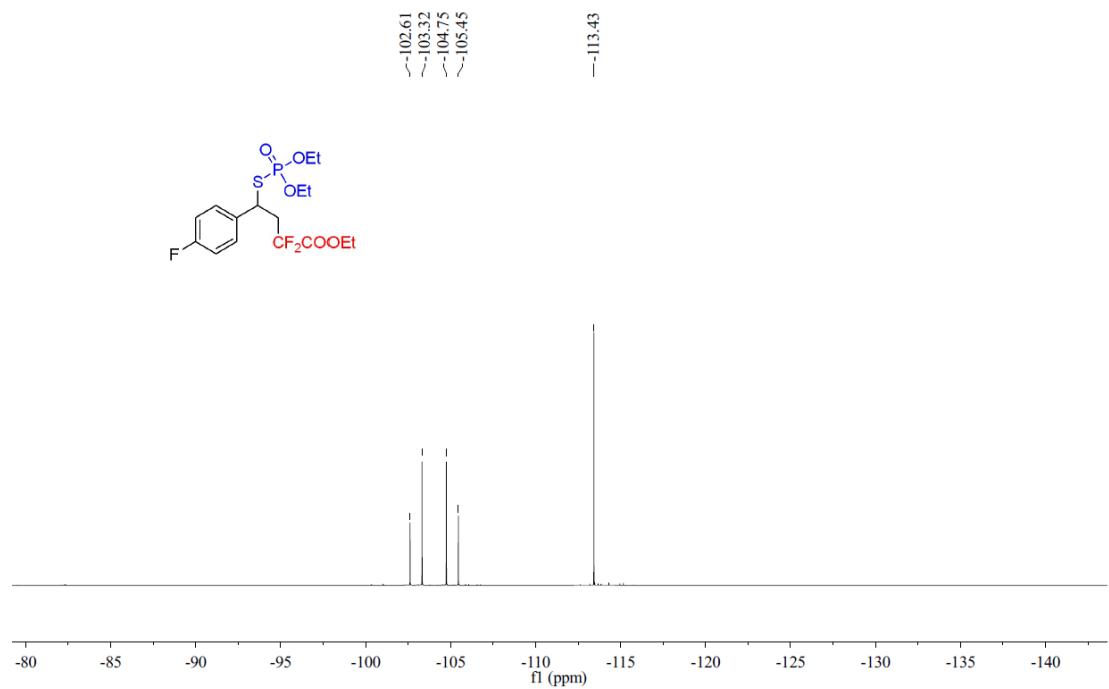
<sup>13</sup>C NMR (151 MHz) Spectrum of **4i** in CDCl<sub>3</sub>



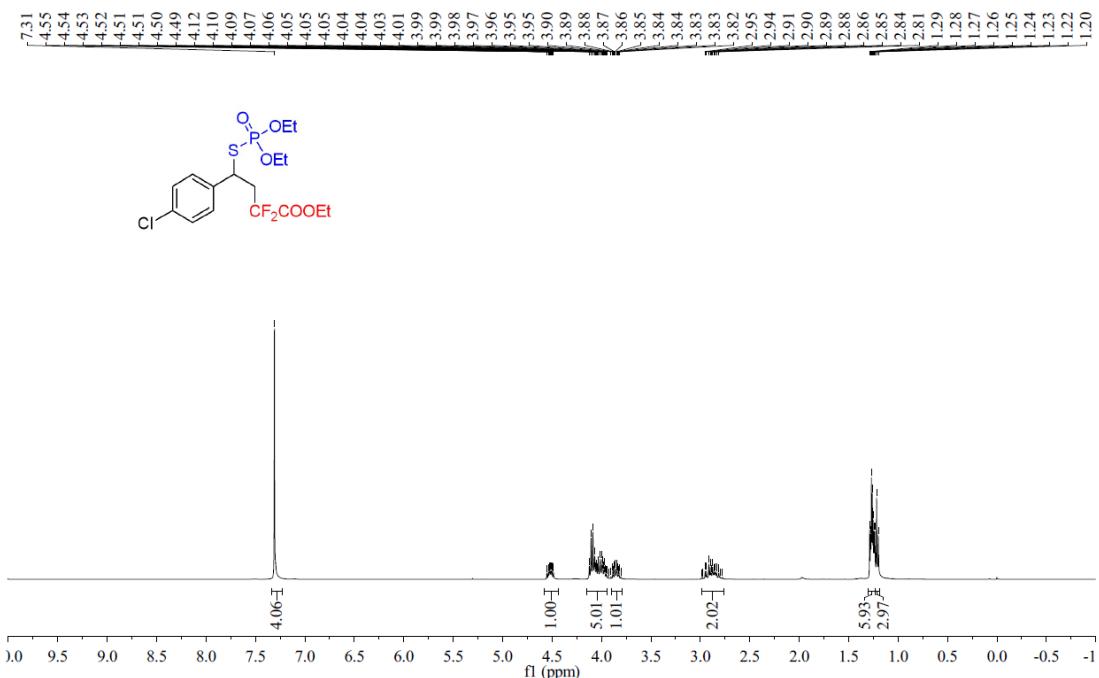
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4i** in  $\text{CDCl}_3$



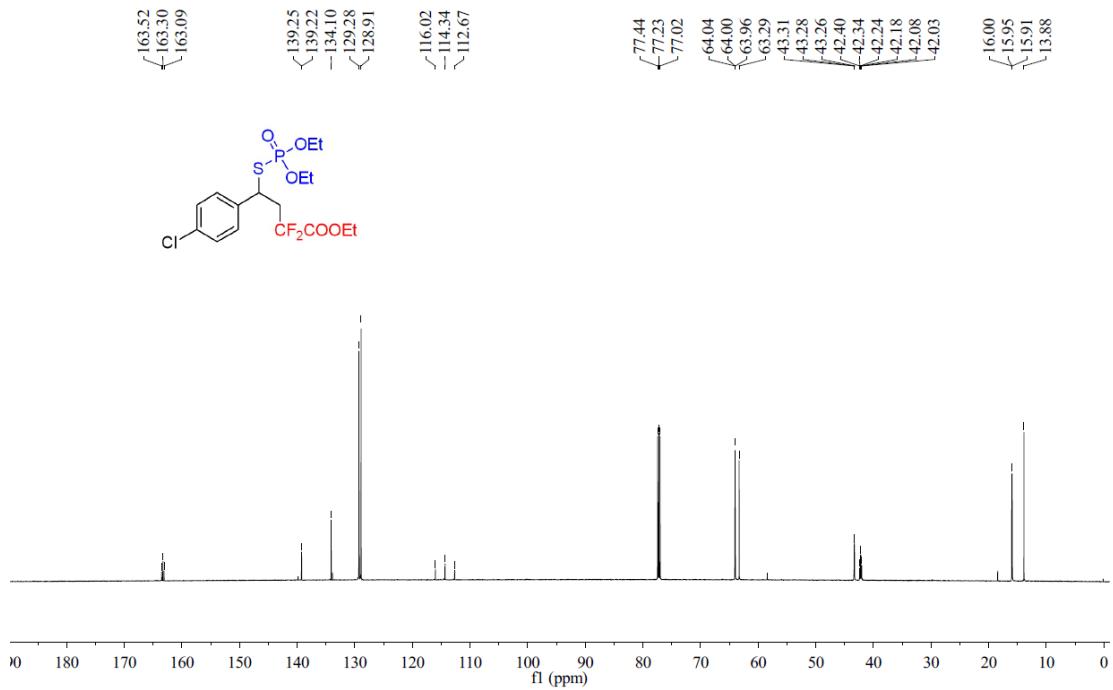
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4i** in  $\text{CDCl}_3$



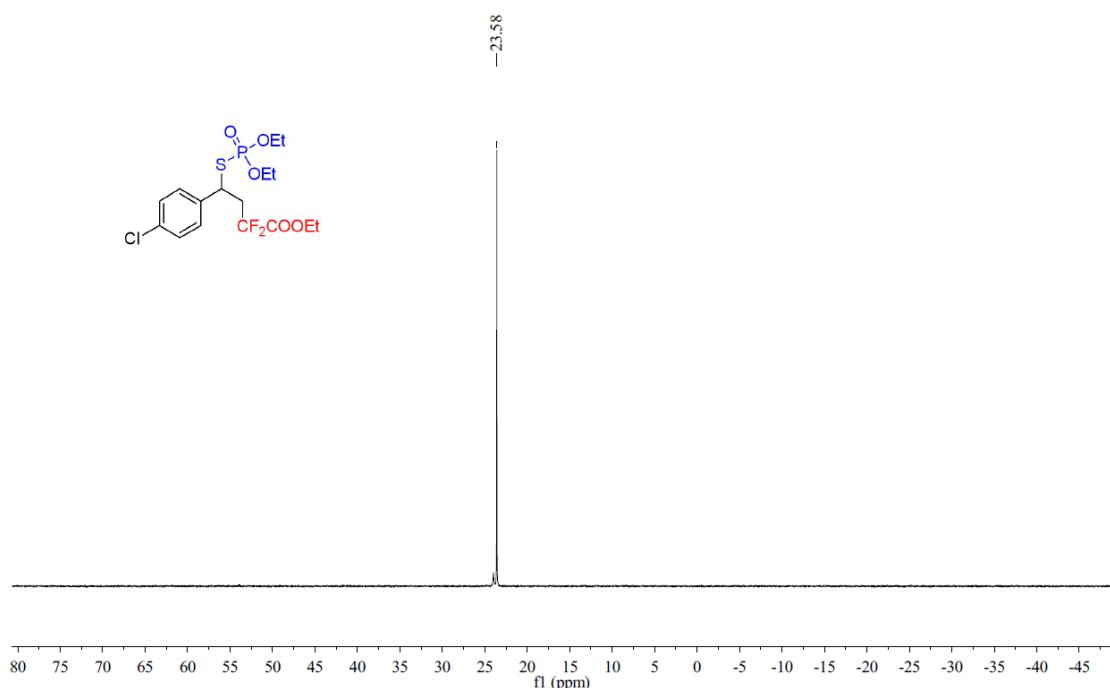
<sup>1</sup>H NMR (400 MHz) Spectrum of **4j** in CDCl<sub>3</sub>



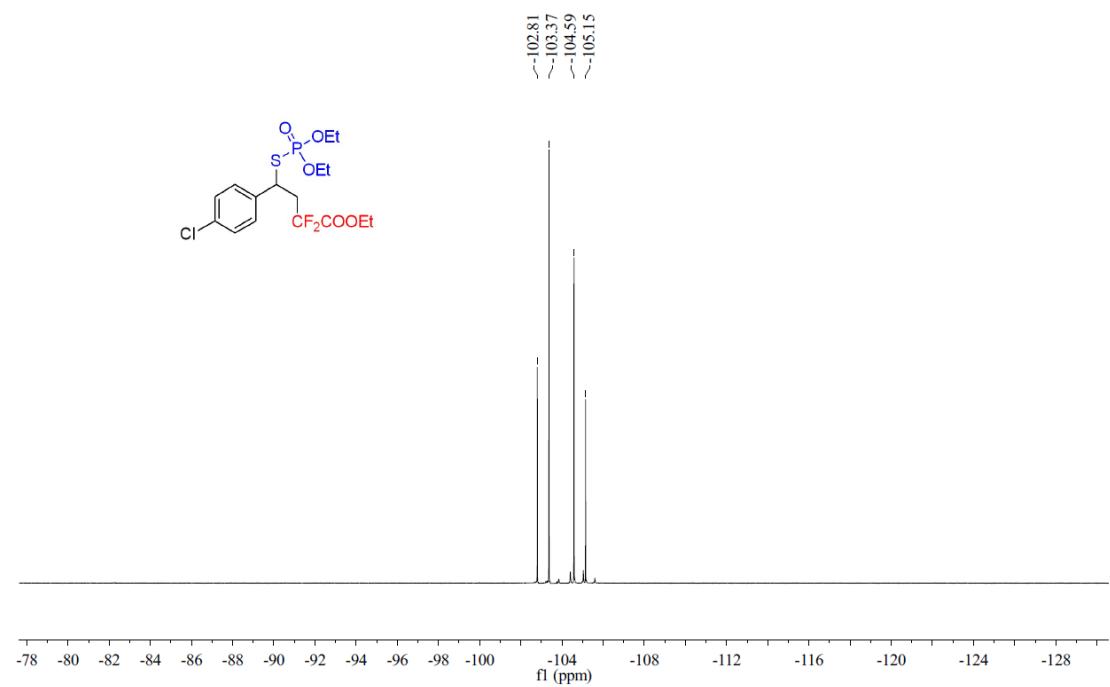
<sup>13</sup>C NMR (151 MHz) Spectrum of **4j** in CDCl<sub>3</sub>



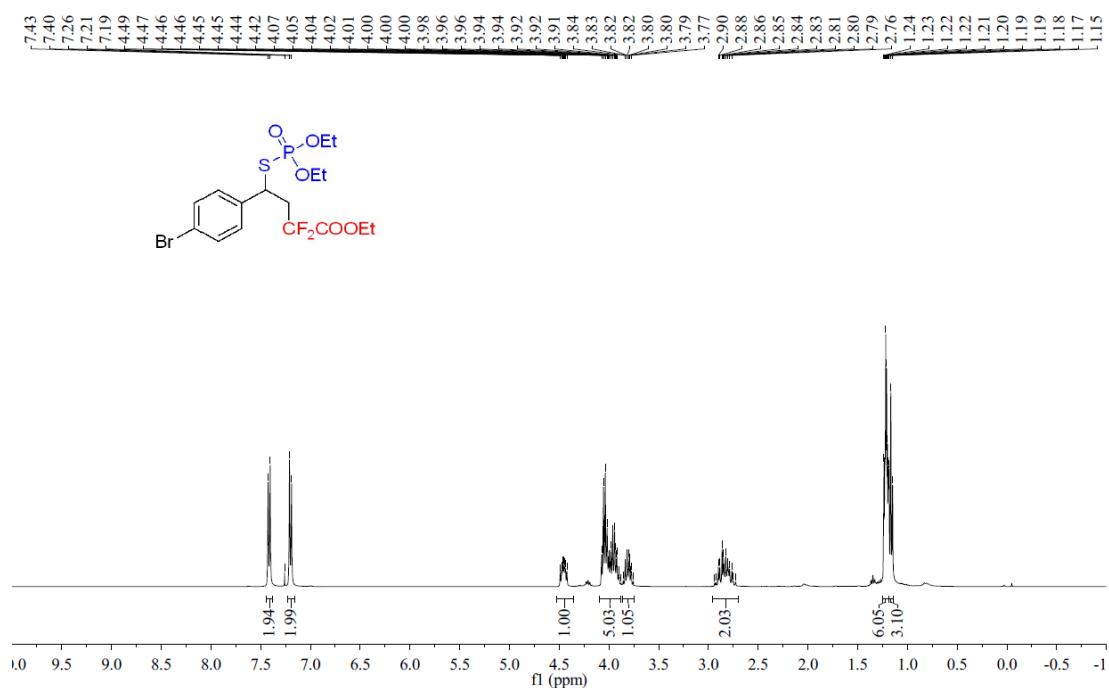
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4j** in  $\text{CDCl}_3$



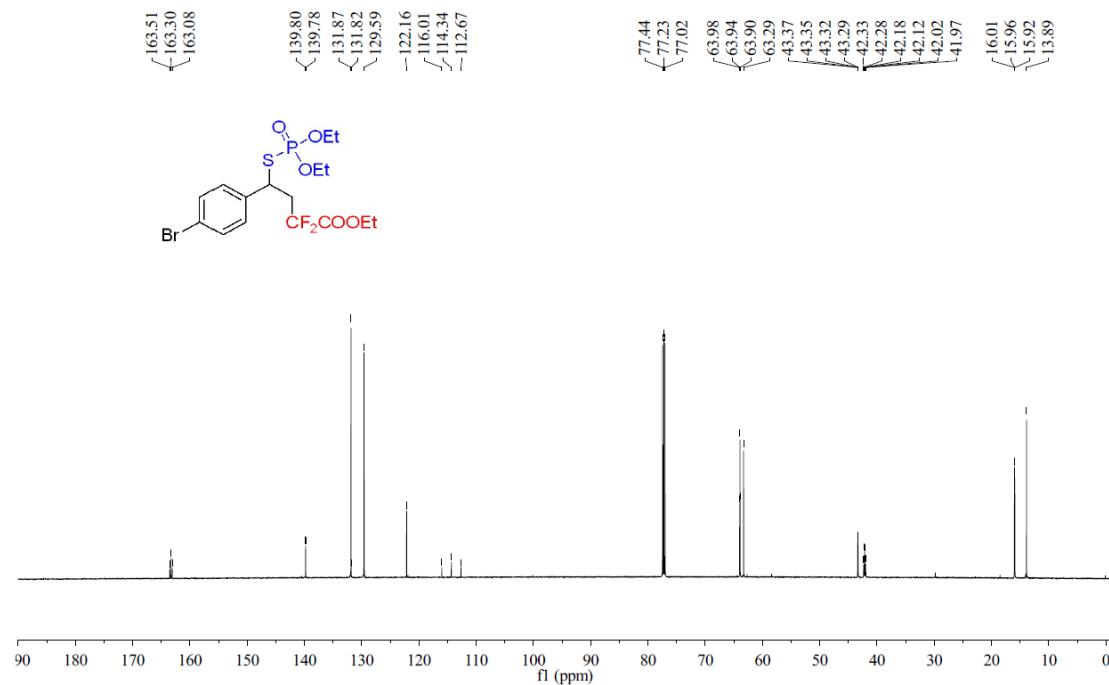
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4j** in  $\text{CDCl}_3$



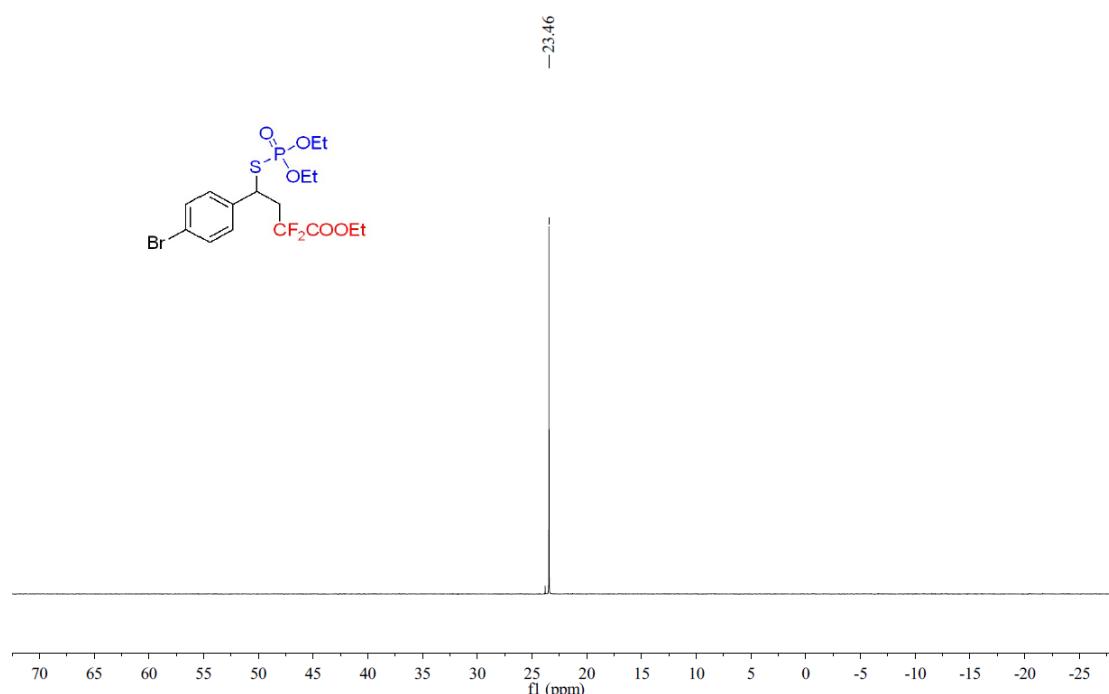
<sup>1</sup>H NMR (400 MHz) Spectrum of **4k** in CDCl<sub>3</sub>



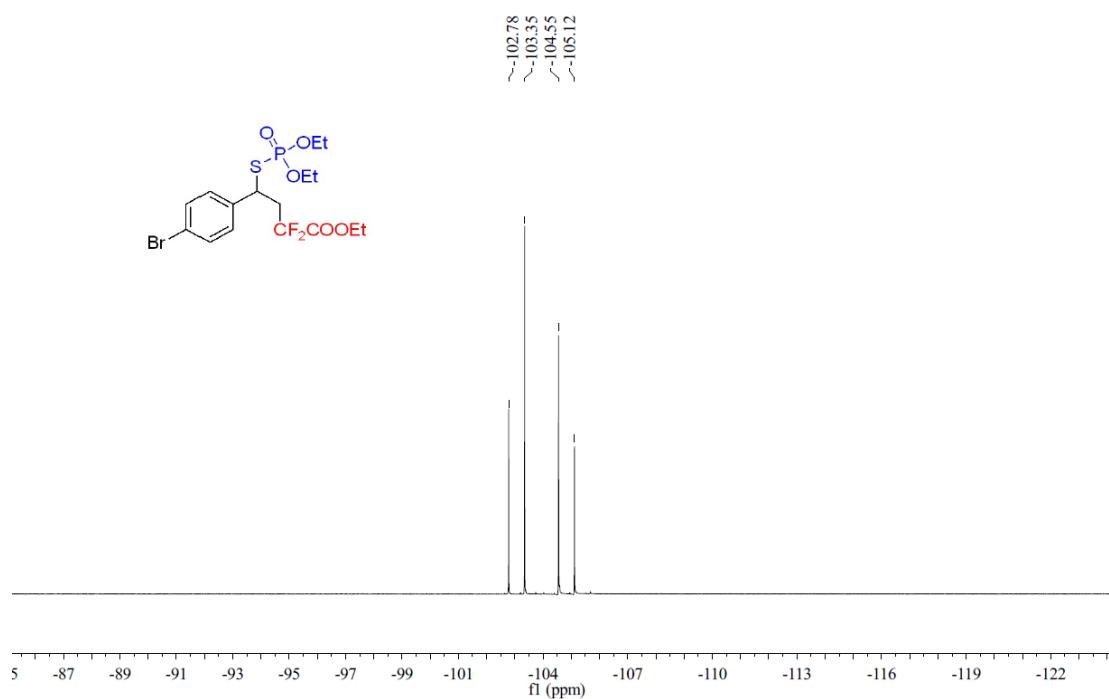
<sup>13</sup>C NMR (151 MHz) Spectrum of **4k** in CDCl<sub>3</sub>



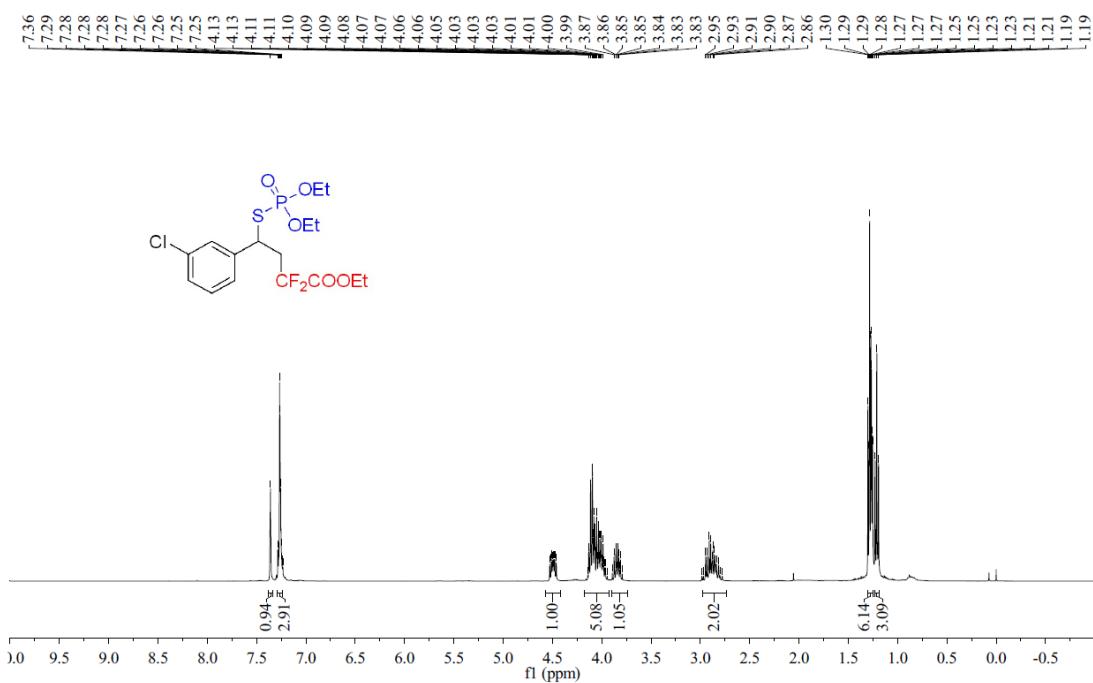
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4k** in  $\text{CDCl}_3$



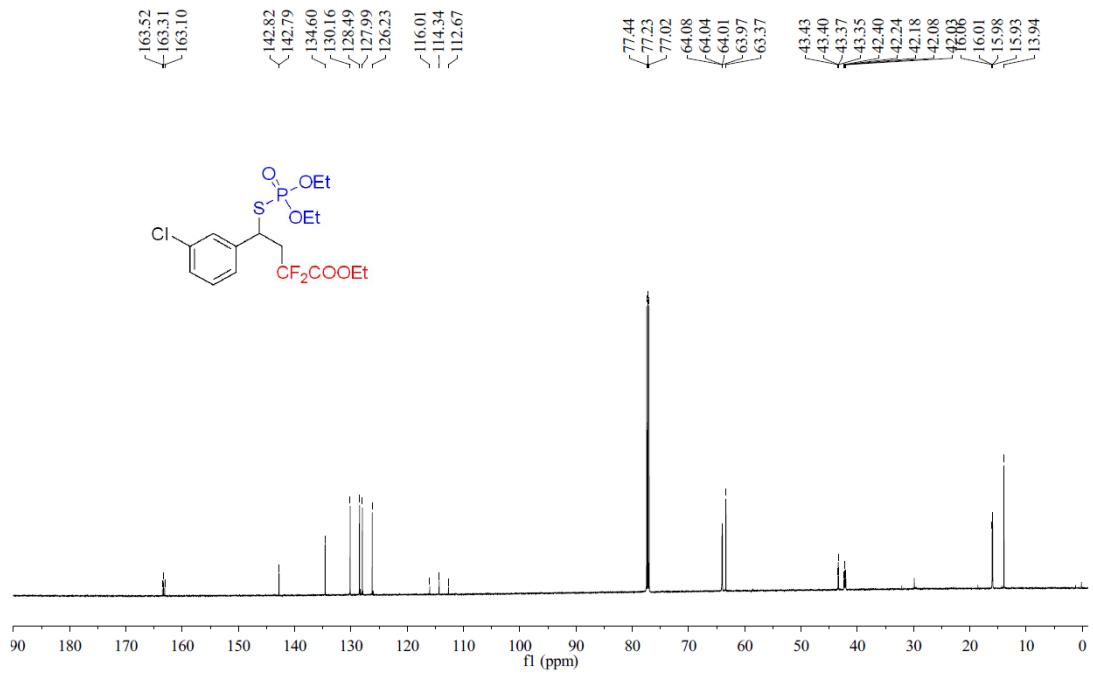
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4k** in  $\text{CDCl}_3$



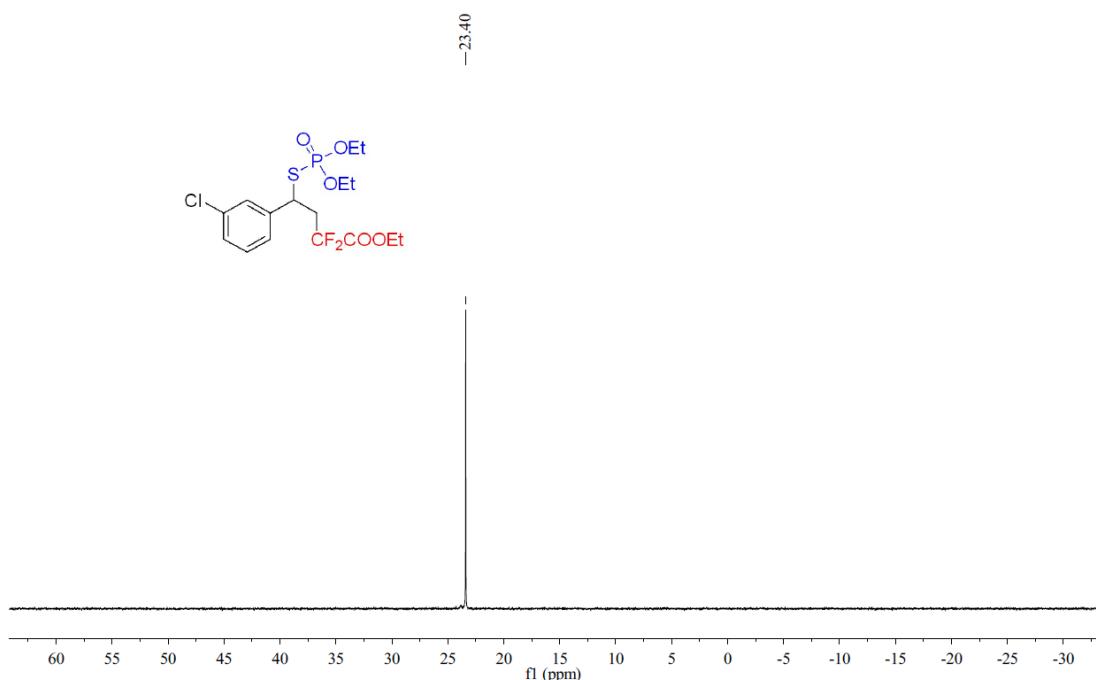
<sup>1</sup>H NMR (400 MHz) Spectrum of **4I** in CDCl<sub>3</sub>



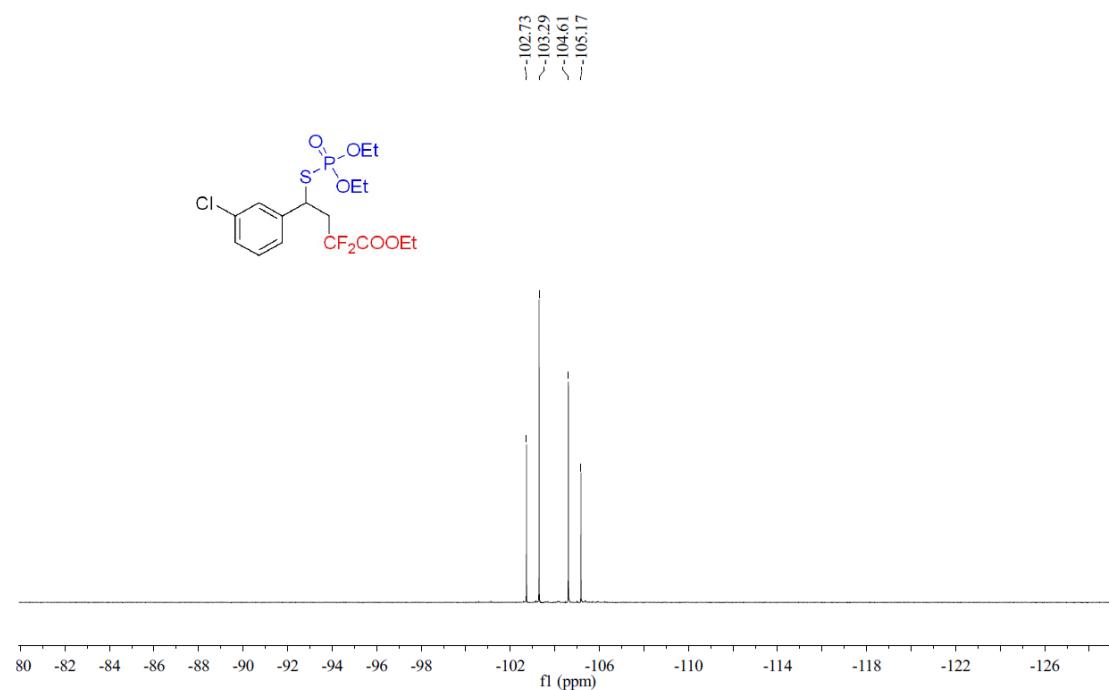
<sup>13</sup>C NMR (151 MHz) Spectrum of **4l** in CDCl<sub>3</sub>



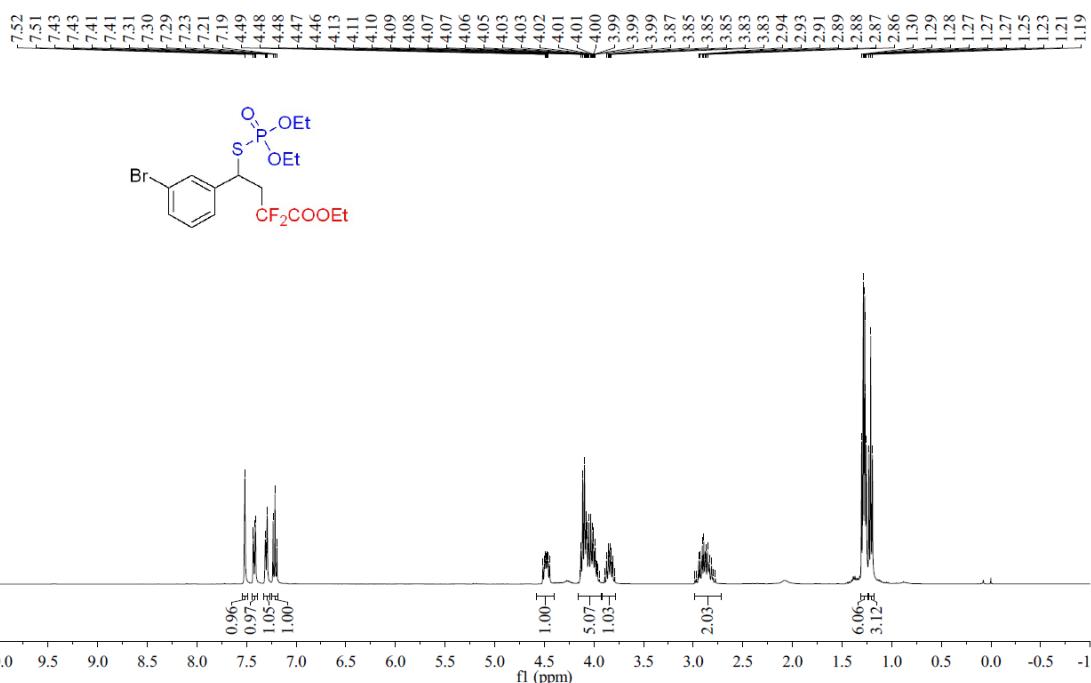
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4l** in  $\text{CDCl}_3$



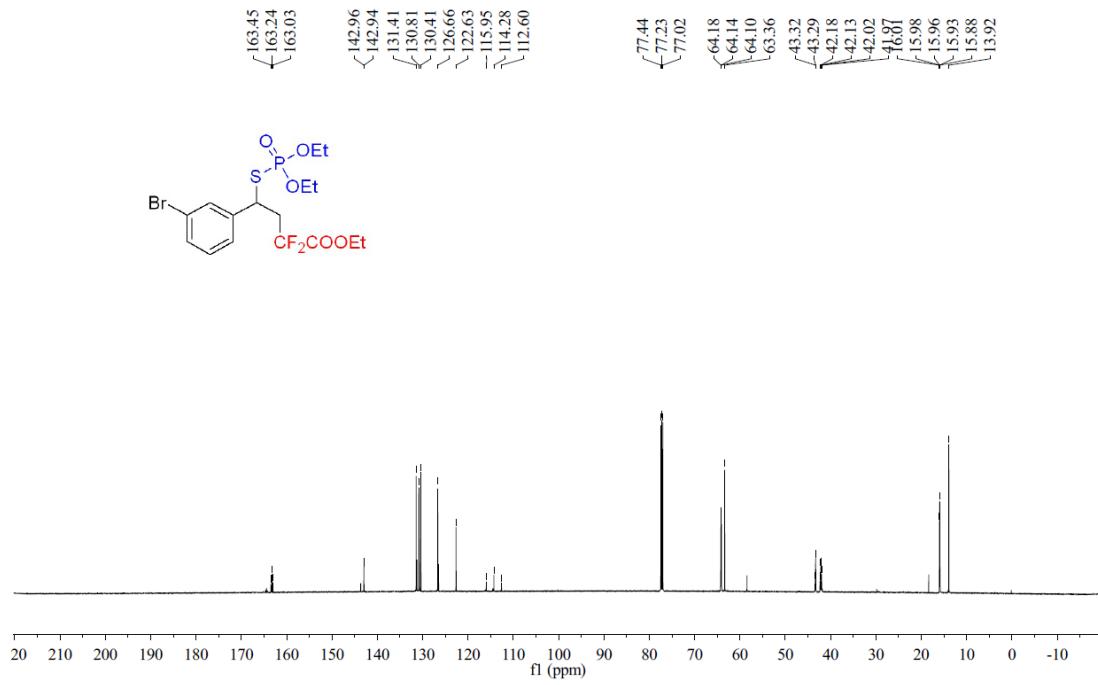
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4l** in  $\text{CDCl}_3$



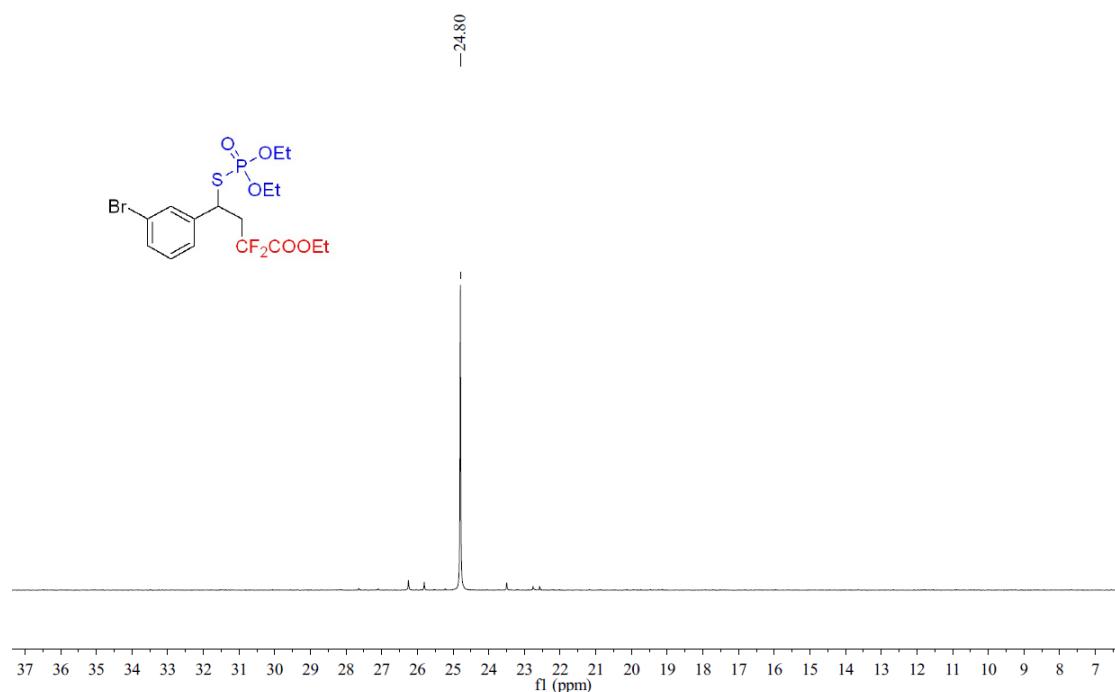
<sup>1</sup>H NMR (400 MHz) Spectrum of **4m** in CDCl<sub>3</sub>



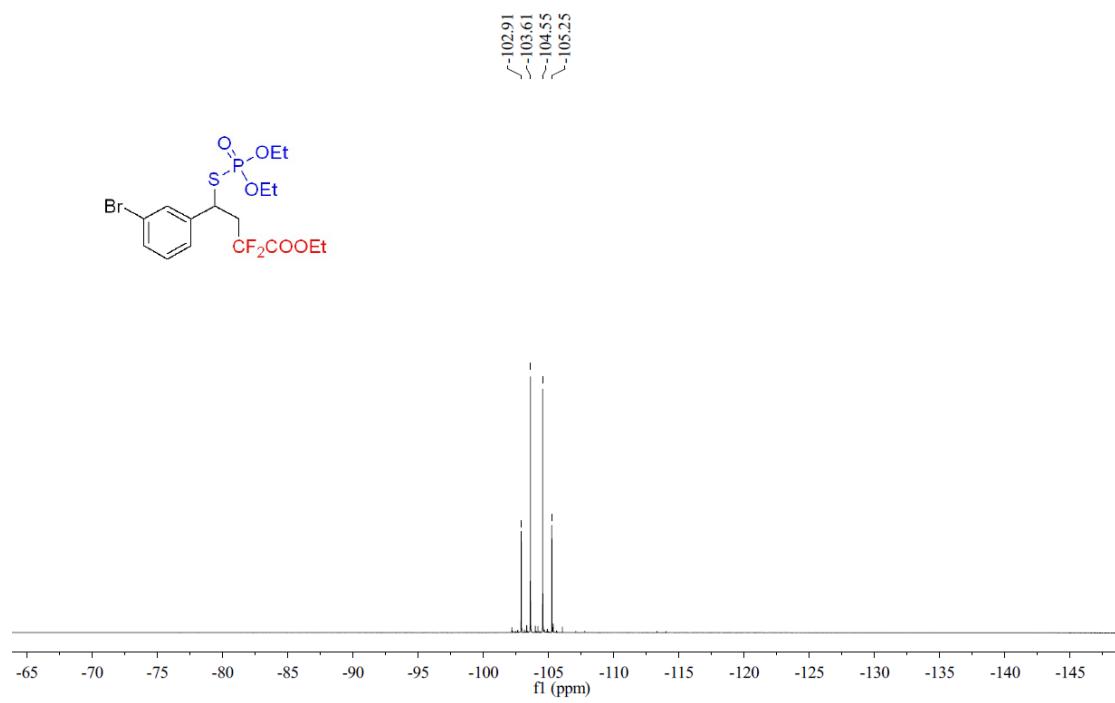
<sup>13</sup>C NMR (151 MHz) Spectrum of **4m** in CDCl<sub>3</sub>



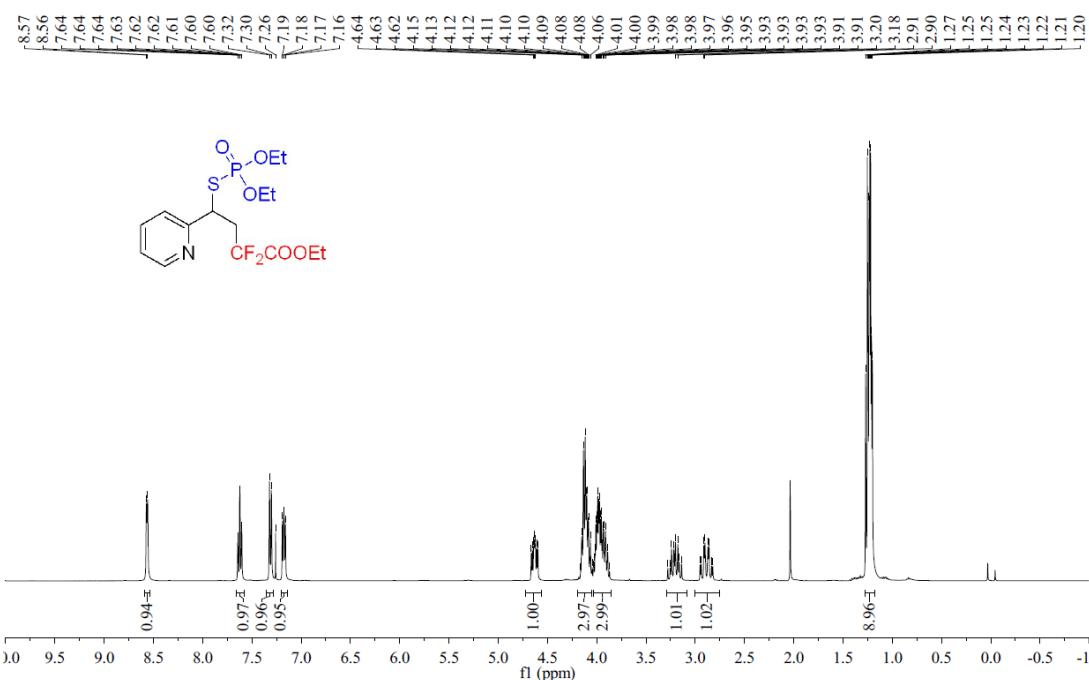
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4m** in  $\text{CDCl}_3$



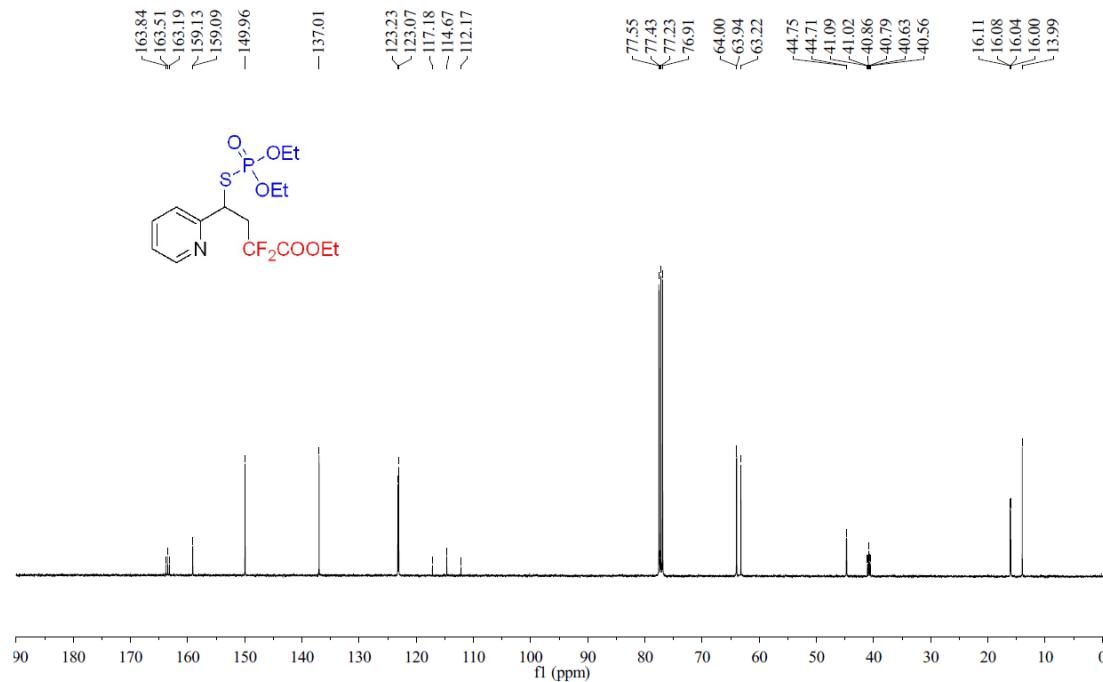
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4m** in  $\text{CDCl}_3$



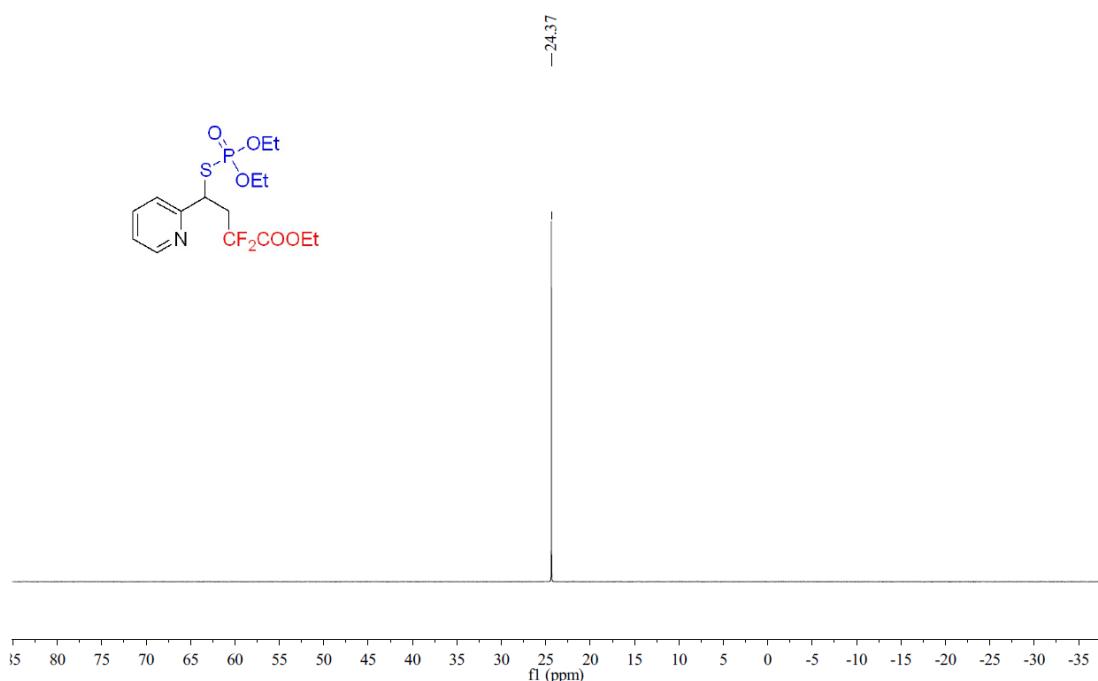
<sup>1</sup>H NMR (400 MHz) Spectrum of **4n** in CDCl<sub>3</sub>



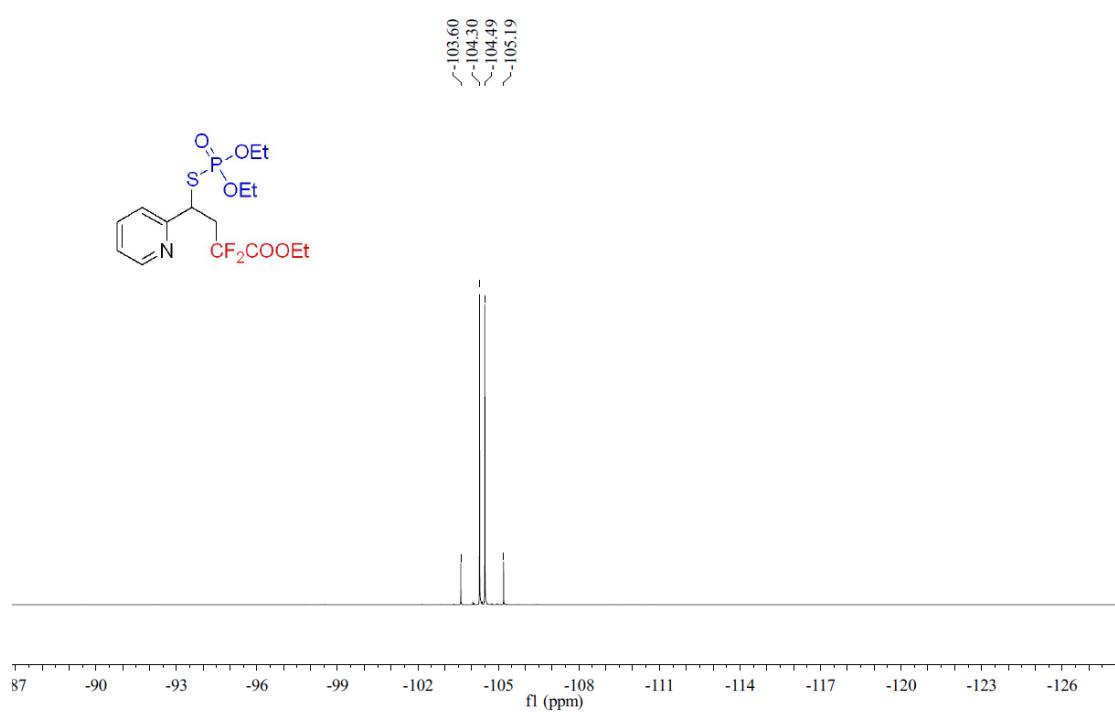
<sup>13</sup>C NMR (151 MHz) Spectrum of **4n** in CDCl<sub>3</sub>



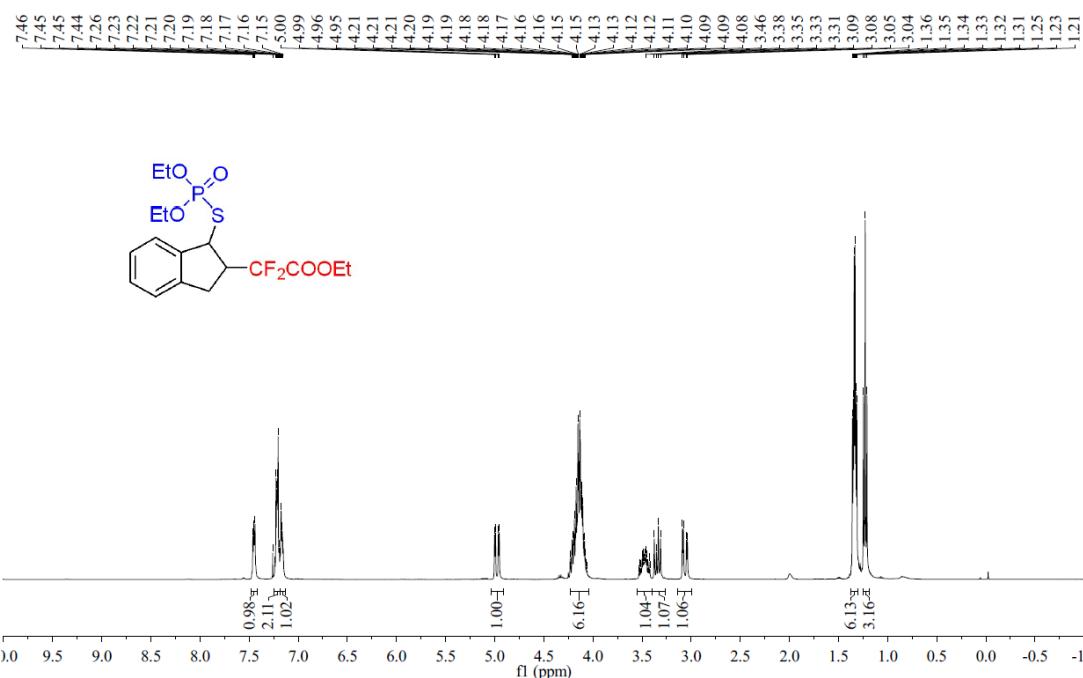
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4n** in  $\text{CDCl}_3$



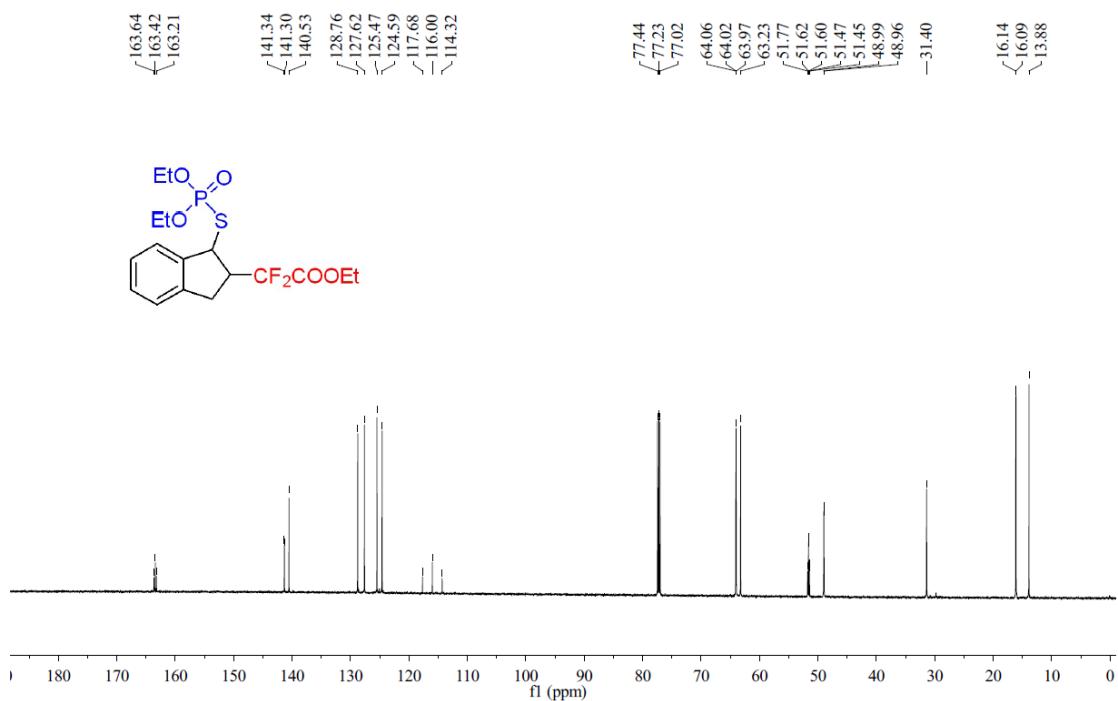
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4n** in  $\text{CDCl}_3$



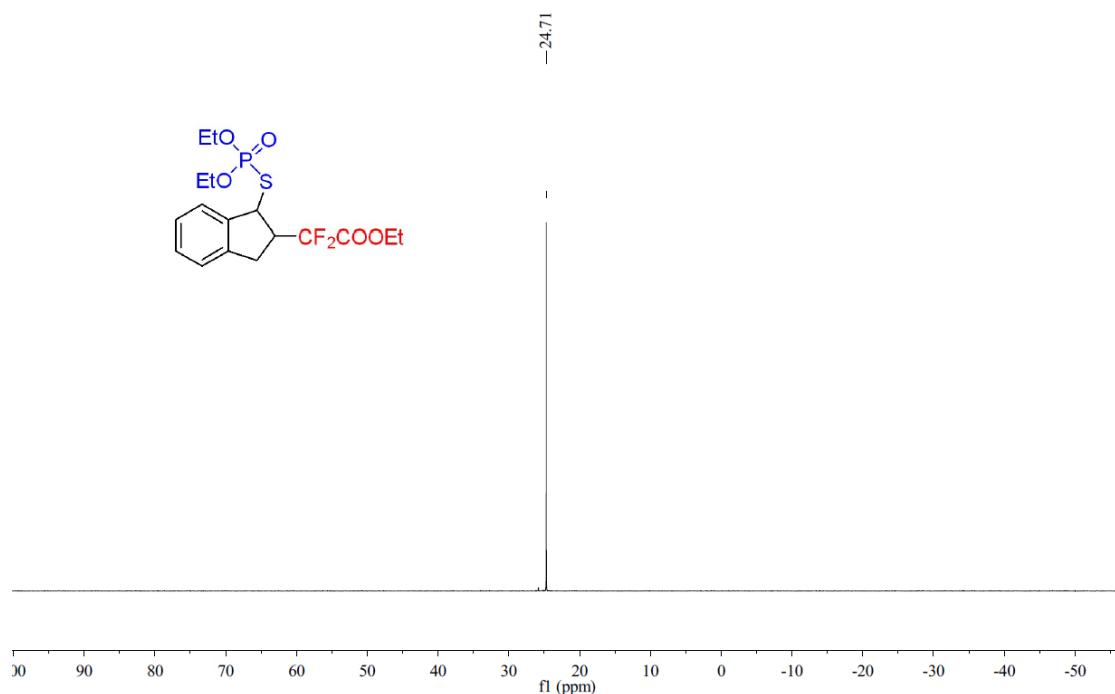
<sup>1</sup>H NMR (400 MHz) Spectrum of **4o** in CDCl<sub>3</sub>



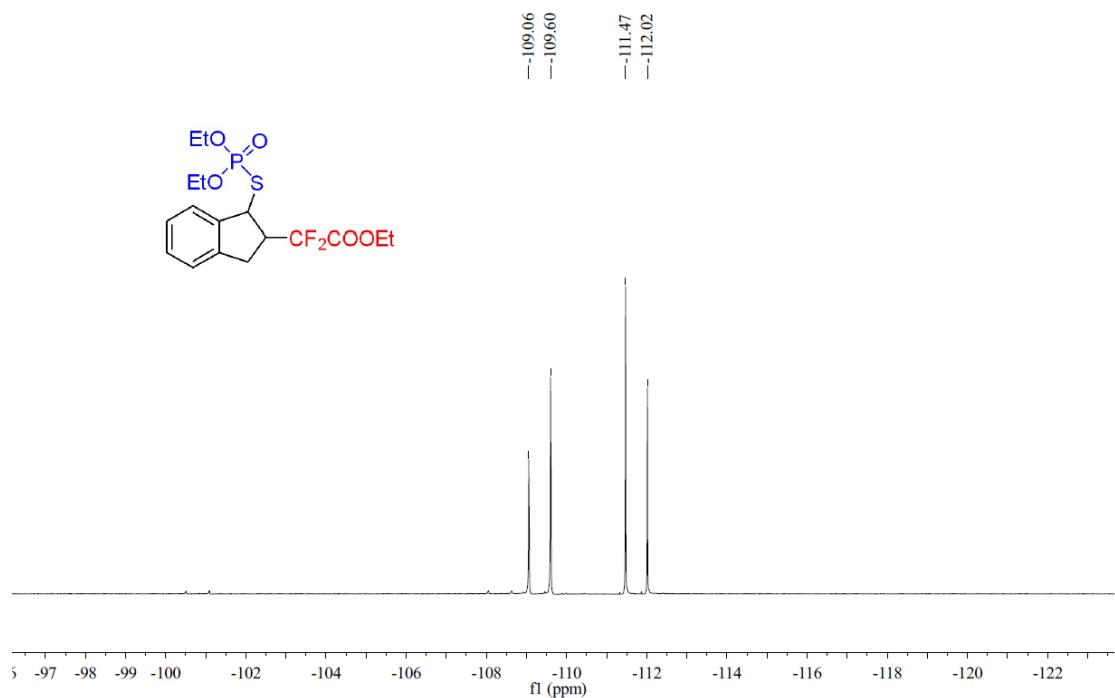
<sup>13</sup>C NMR (151 MHz) Spectrum of **4o** in CDCl<sub>3</sub>



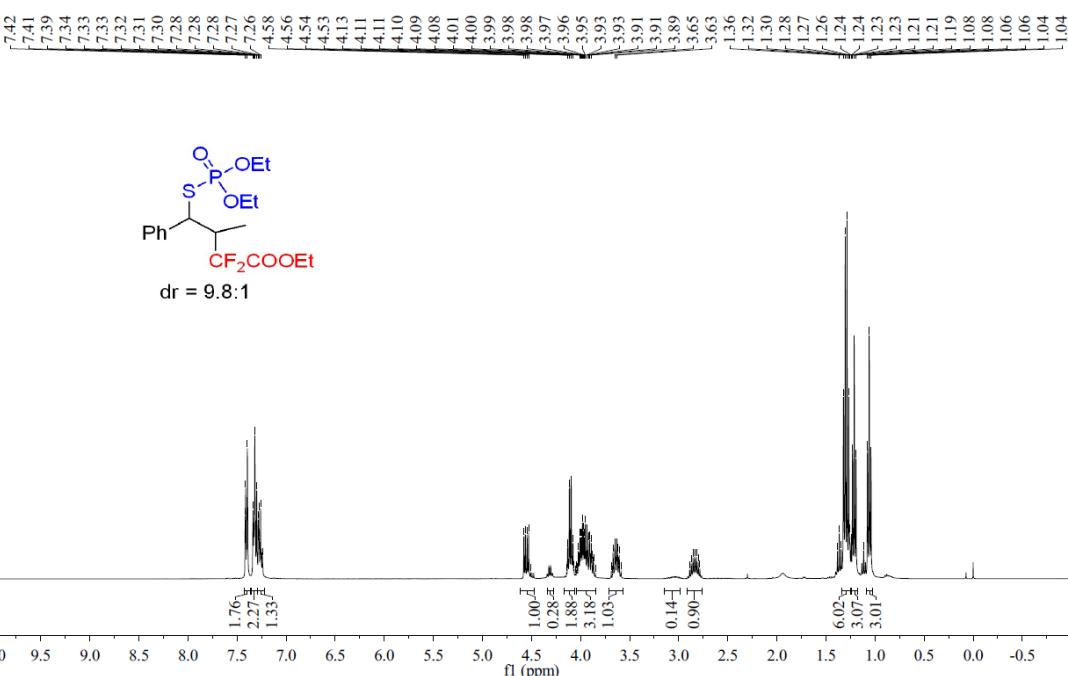
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4o** in  $\text{CDCl}_3$



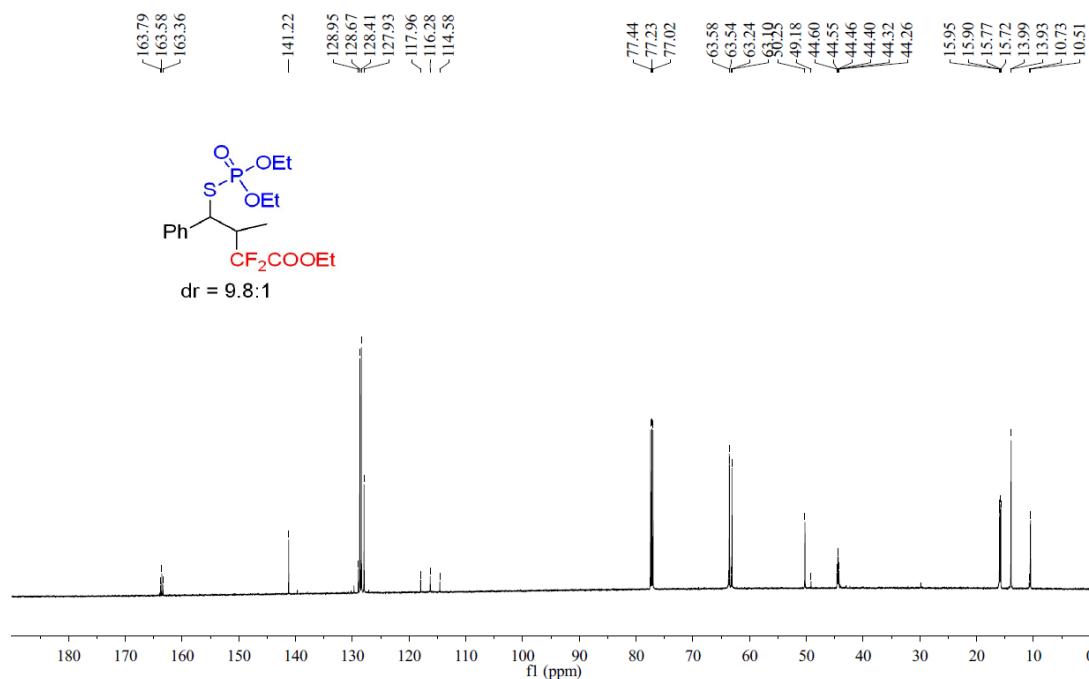
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4o** in  $\text{CDCl}_3$



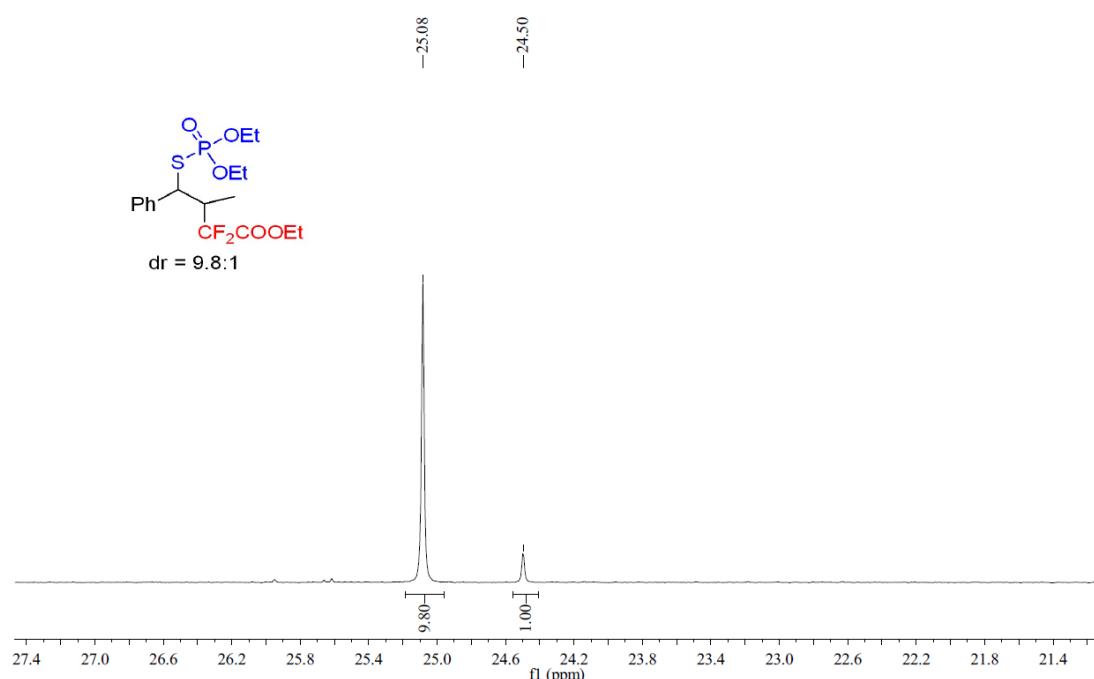
<sup>1</sup>H NMR (400 MHz) Spectrum of **4p** in CDCl<sub>3</sub>



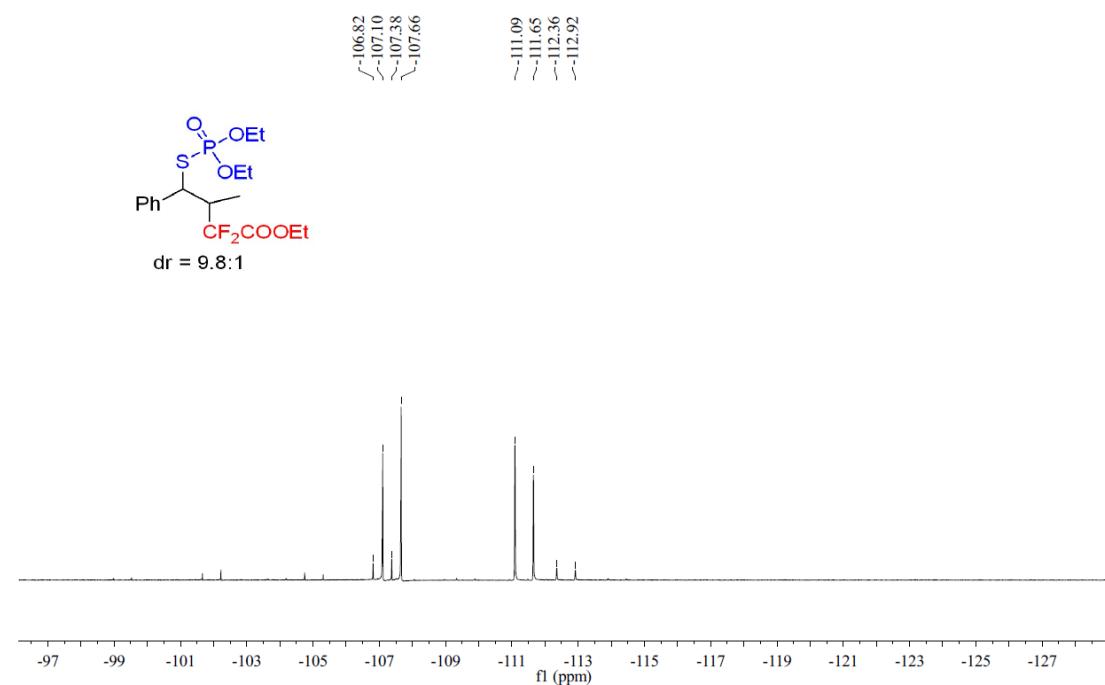
<sup>13</sup>C NMR (151 MHz) Spectrum of **4p** in CDCl<sub>3</sub>



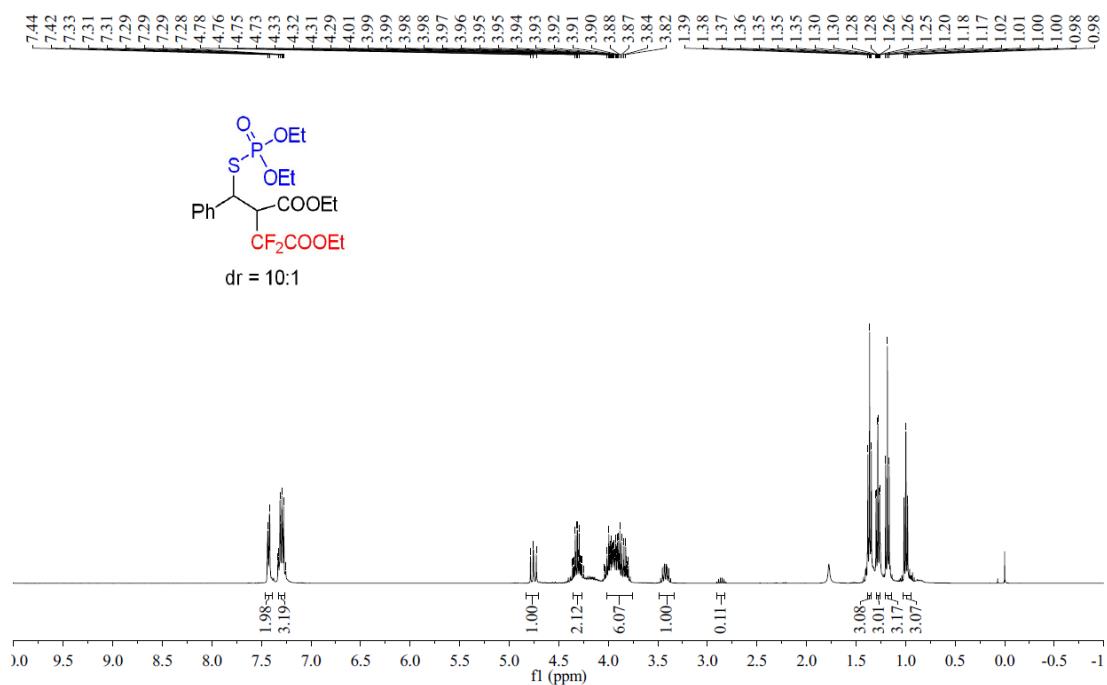
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4p** in  $\text{CDCl}_3$



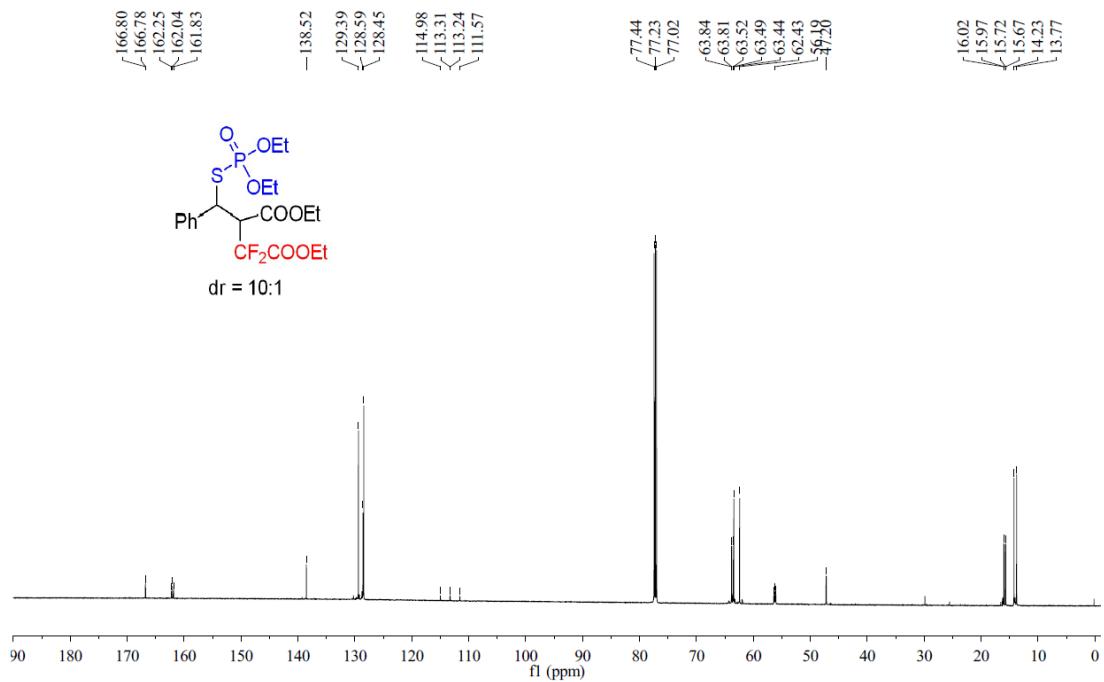
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4p** in  $\text{CDCl}_3$



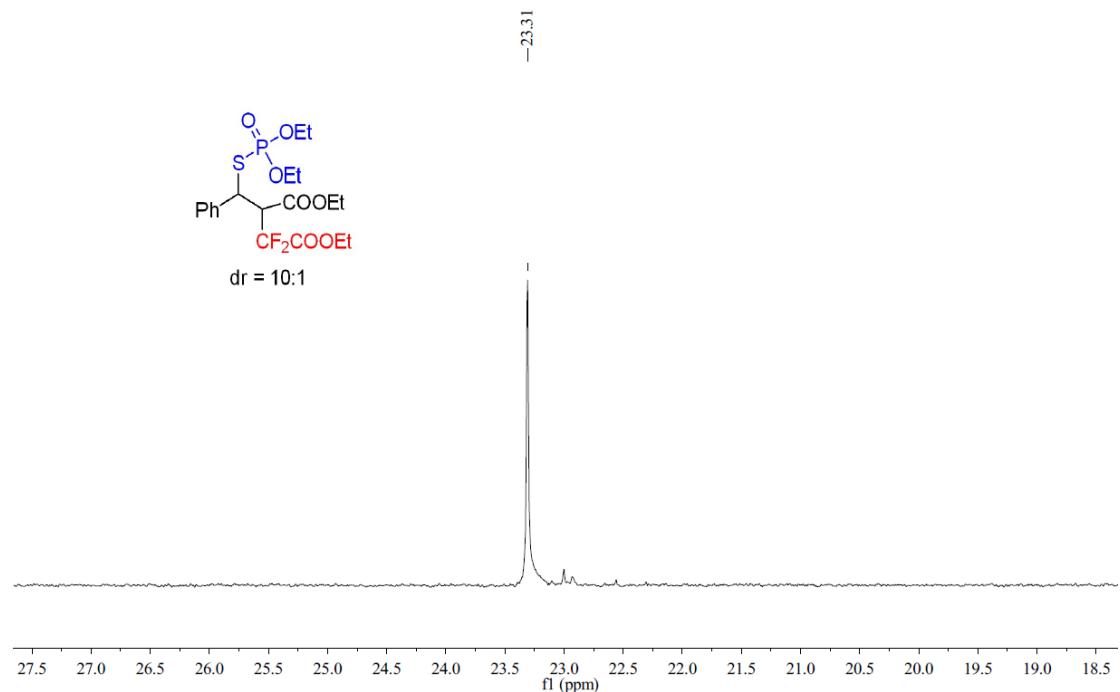
<sup>1</sup>H NMR (400 MHz) Spectrum of **4q** in CDCl<sub>3</sub>



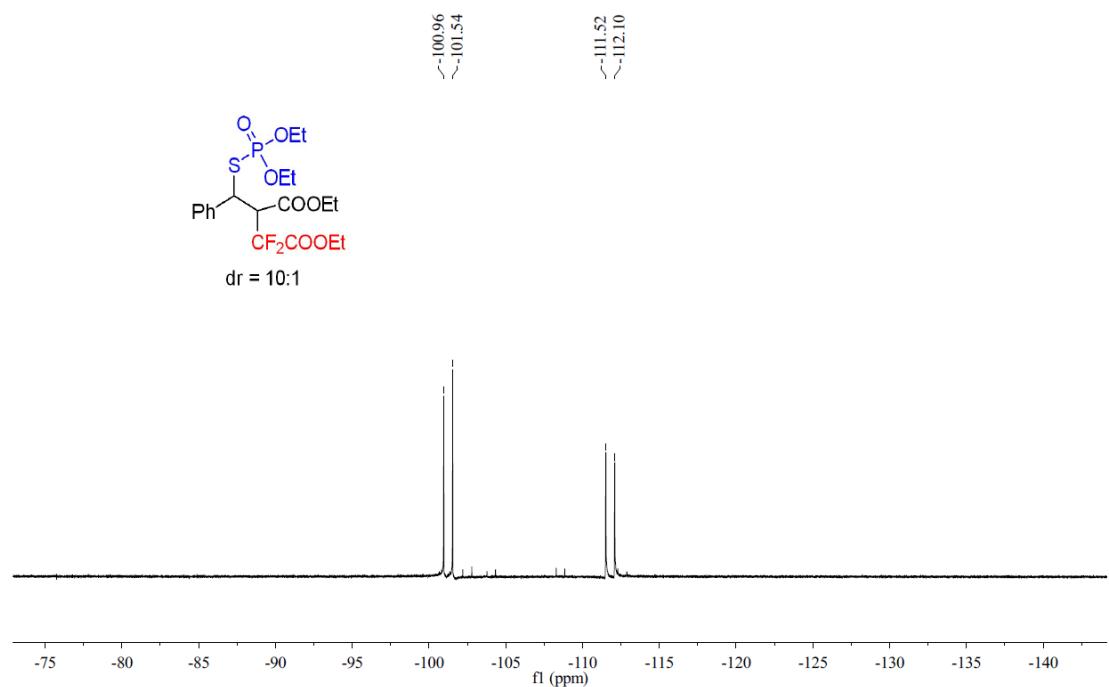
<sup>13</sup>C NMR (151 MHz) Spectrum of **4q** in CDCl<sub>3</sub>



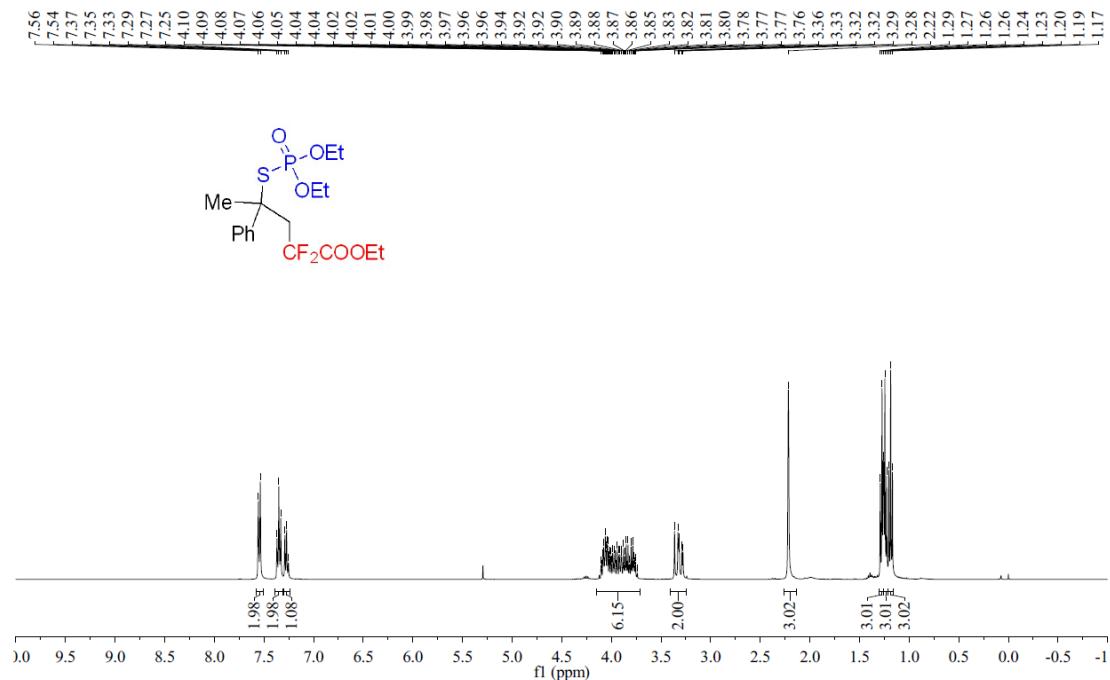
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4q** in  $\text{CDCl}_3$



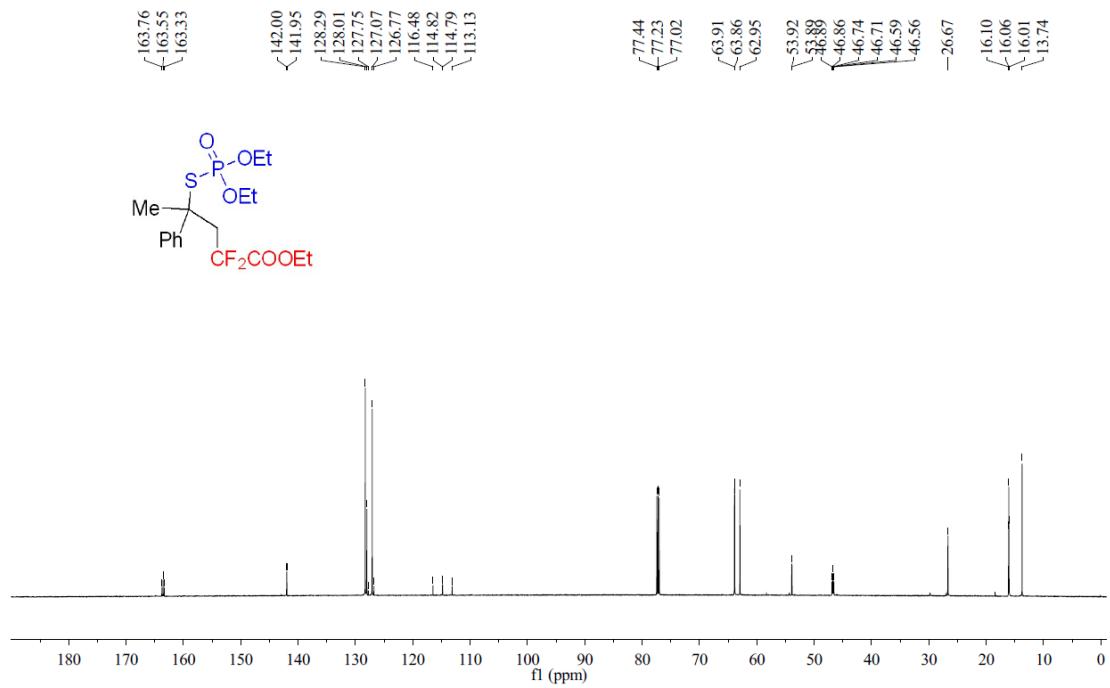
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4q** in  $\text{CDCl}_3$



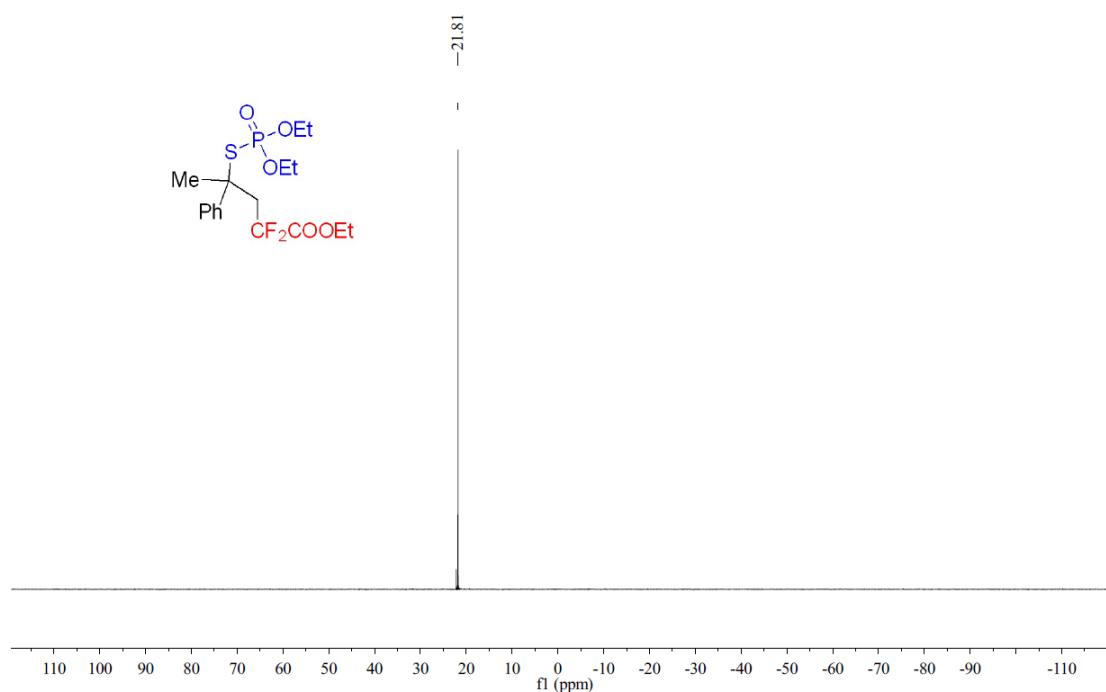
<sup>1</sup>H NMR (400 MHz) Spectrum of **4r** in CDCl<sub>3</sub>



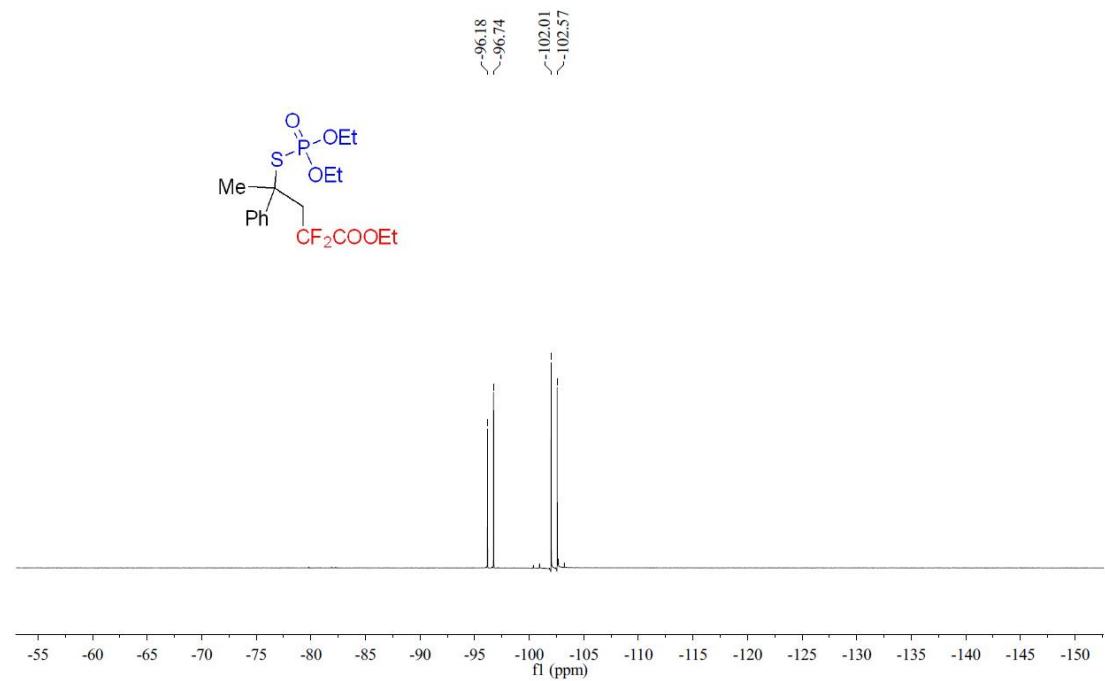
<sup>13</sup>C NMR (151 MHz) Spectrum of **4r** in CDCl<sub>3</sub>



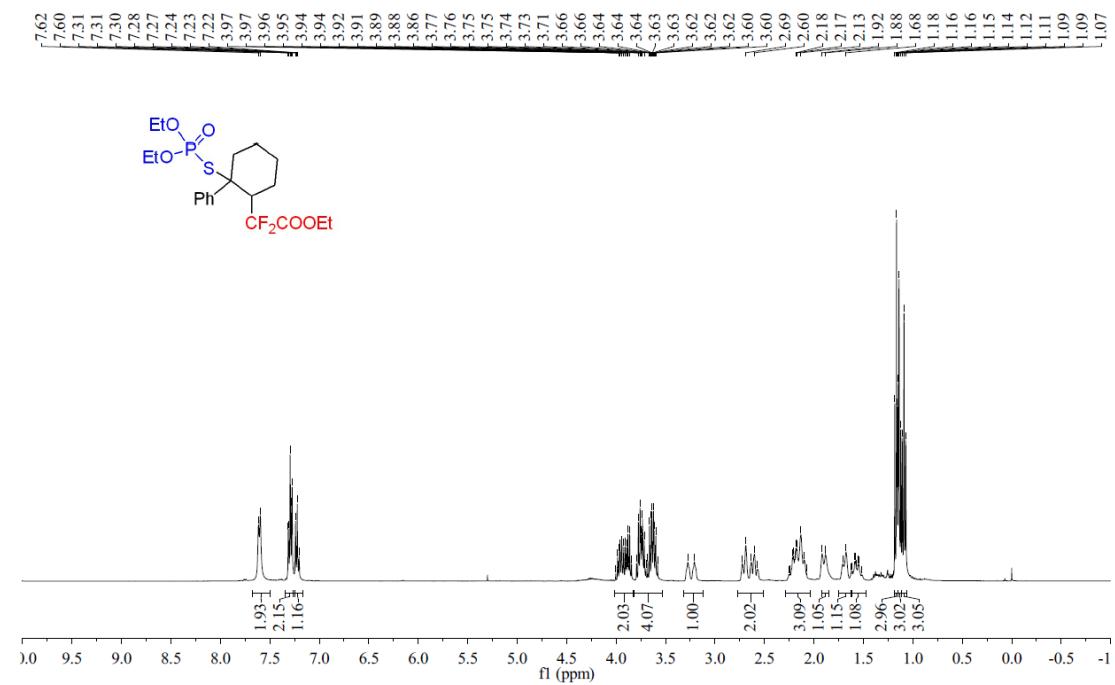
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4r** in  $\text{CDCl}_3$



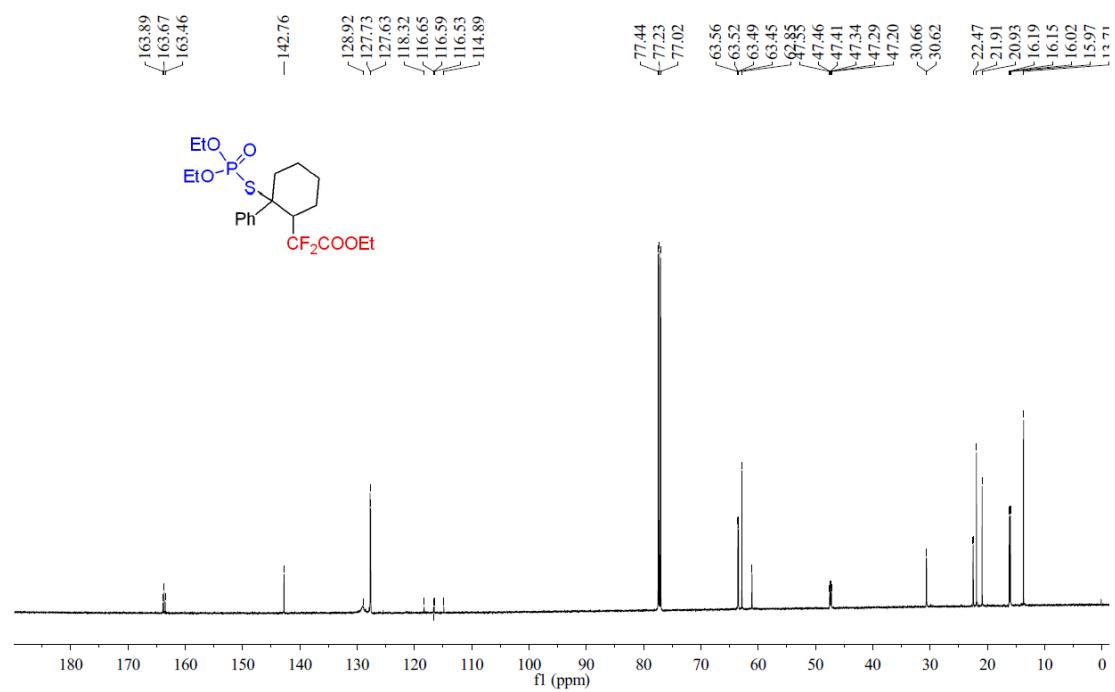
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4r** in  $\text{CDCl}_3$



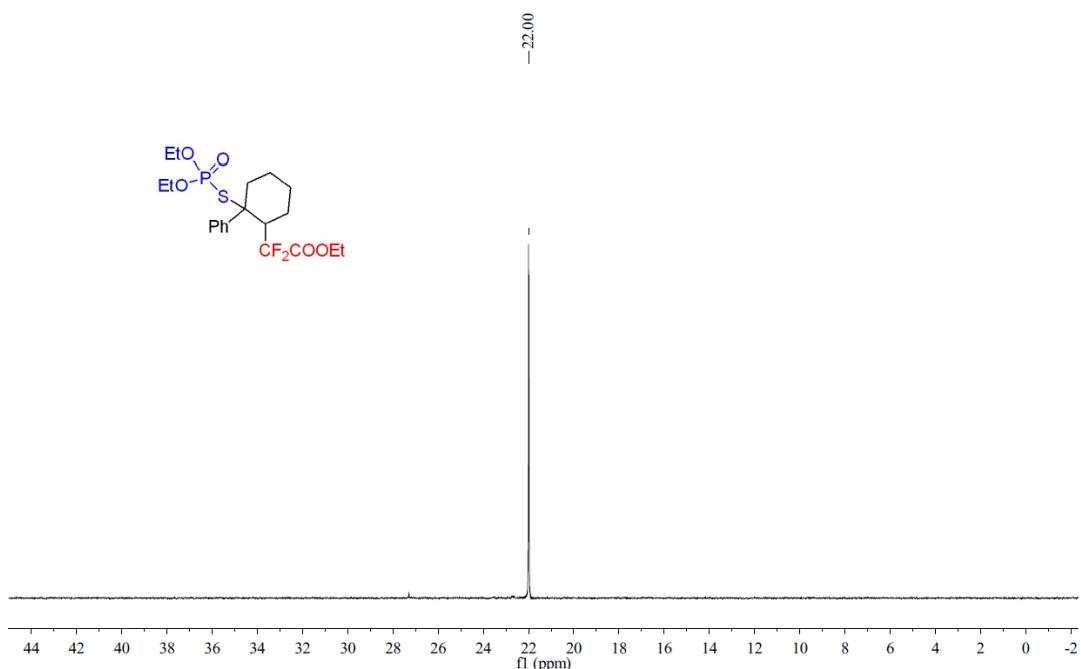
<sup>1</sup>H NMR (400 MHz) Spectrum of **4s** in CDCl<sub>3</sub>



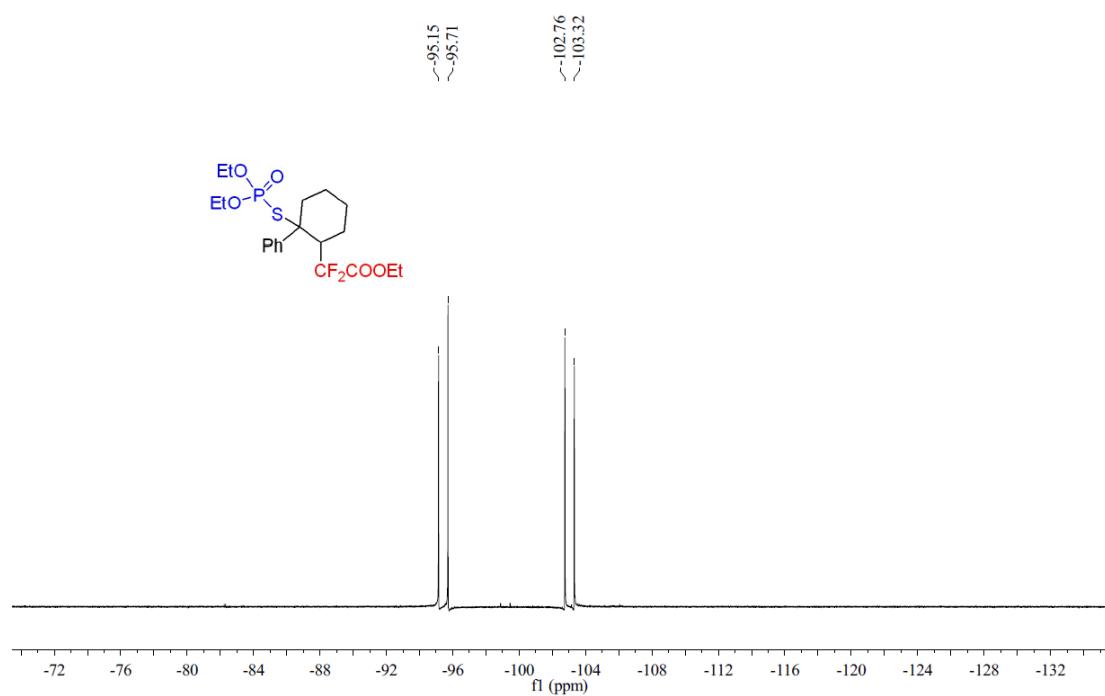
<sup>13</sup>C NMR (151 MHz) Spectrum of **4s** in CDCl<sub>3</sub>



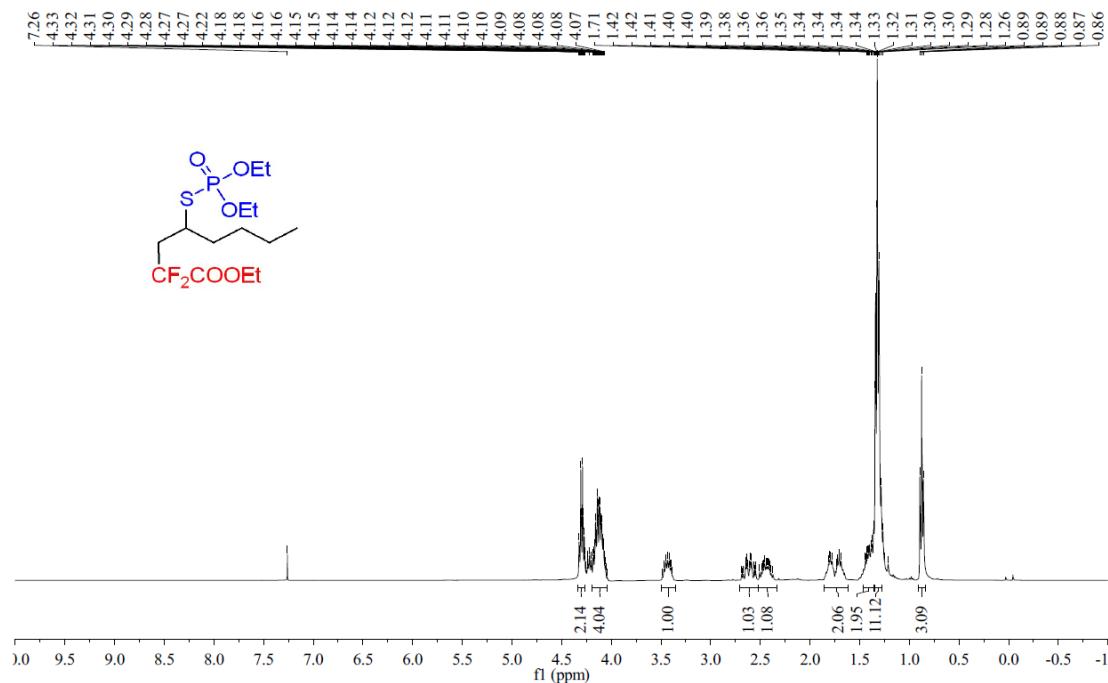
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **4s** in  $\text{CDCl}_3$



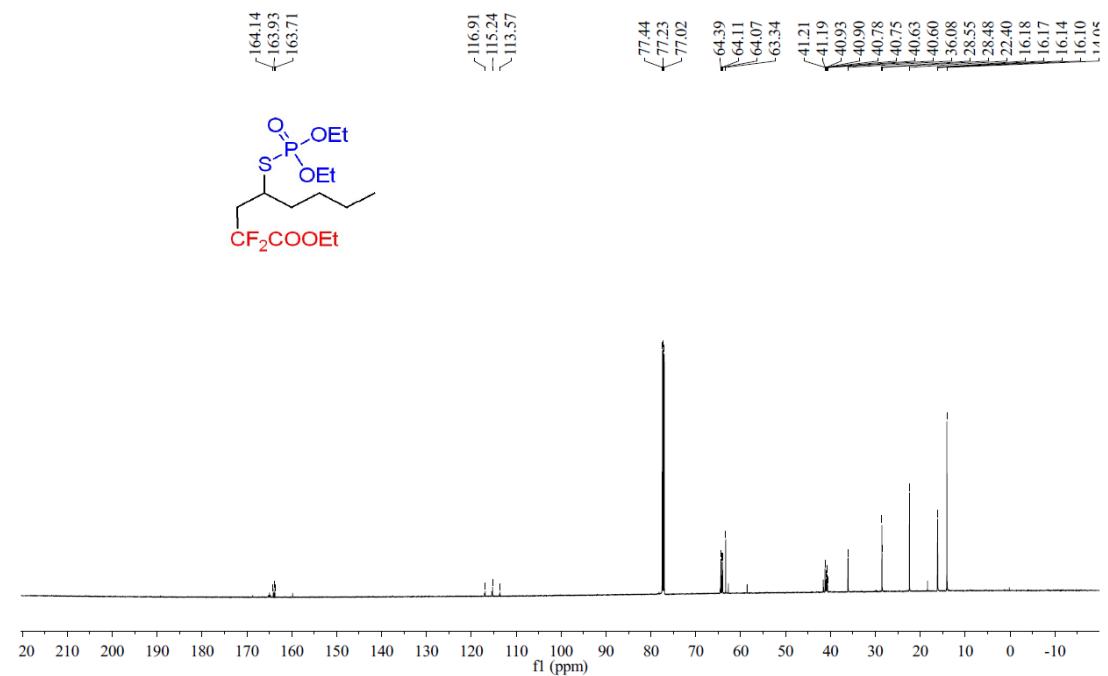
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **4s** in  $\text{CDCl}_3$



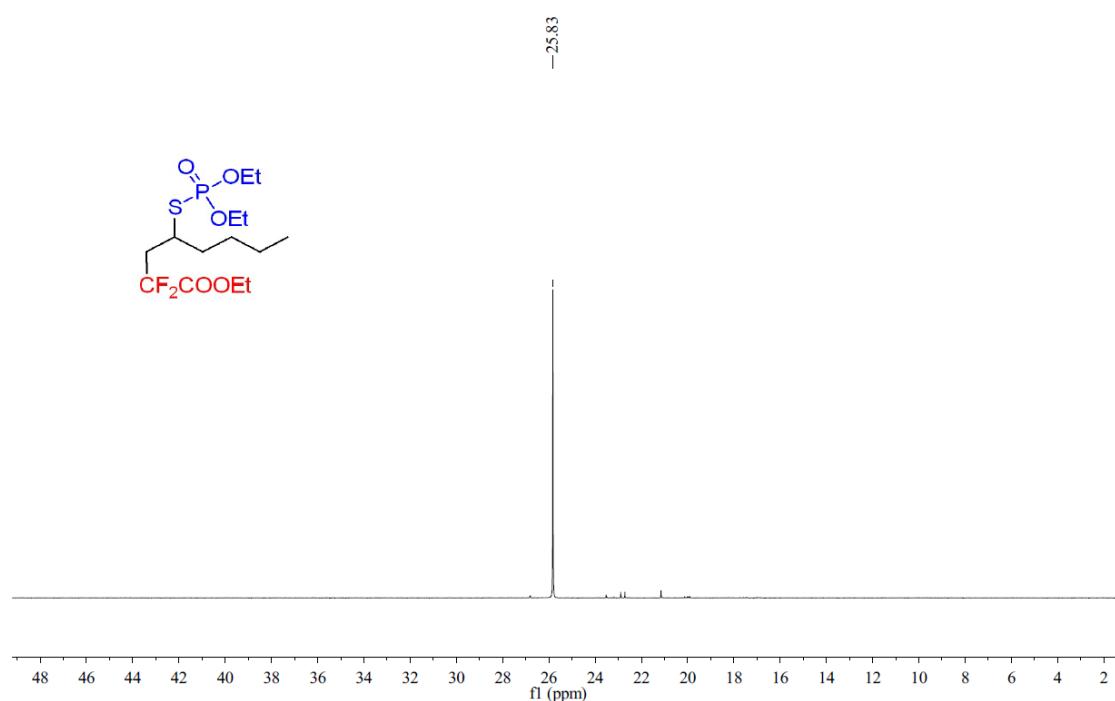
<sup>1</sup>H NMR (400 MHz) Spectrum of **5a** in CDCl<sub>3</sub>



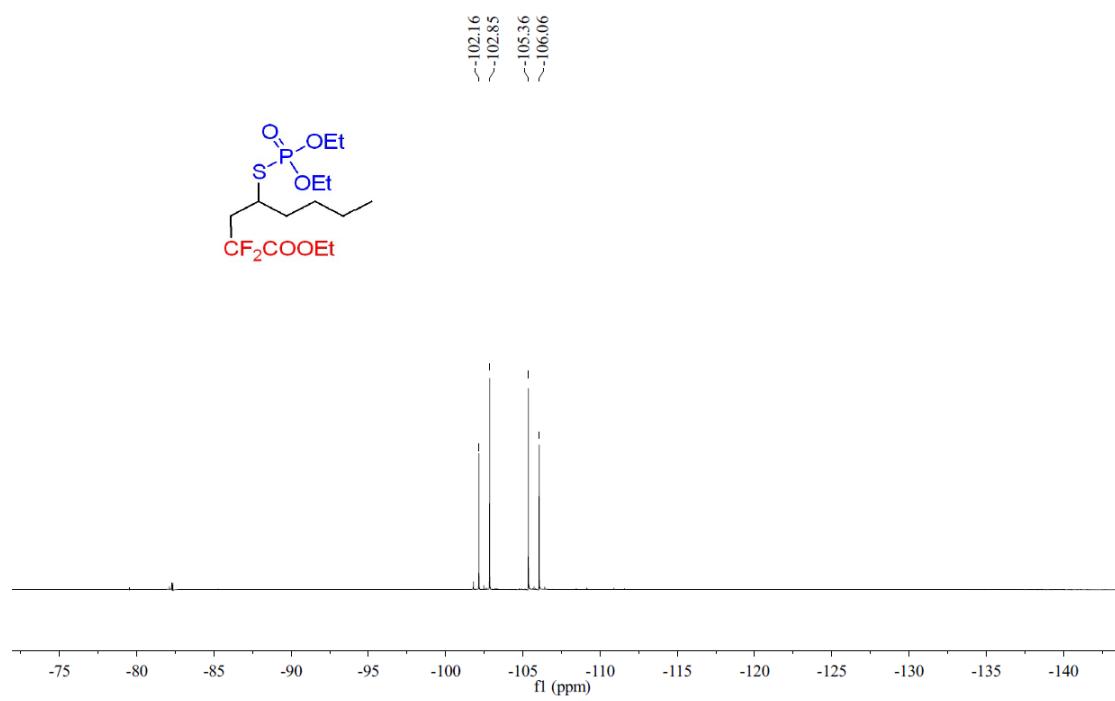
<sup>13</sup>C NMR (151 MHz) Spectrum of **5a** in CDCl<sub>3</sub>



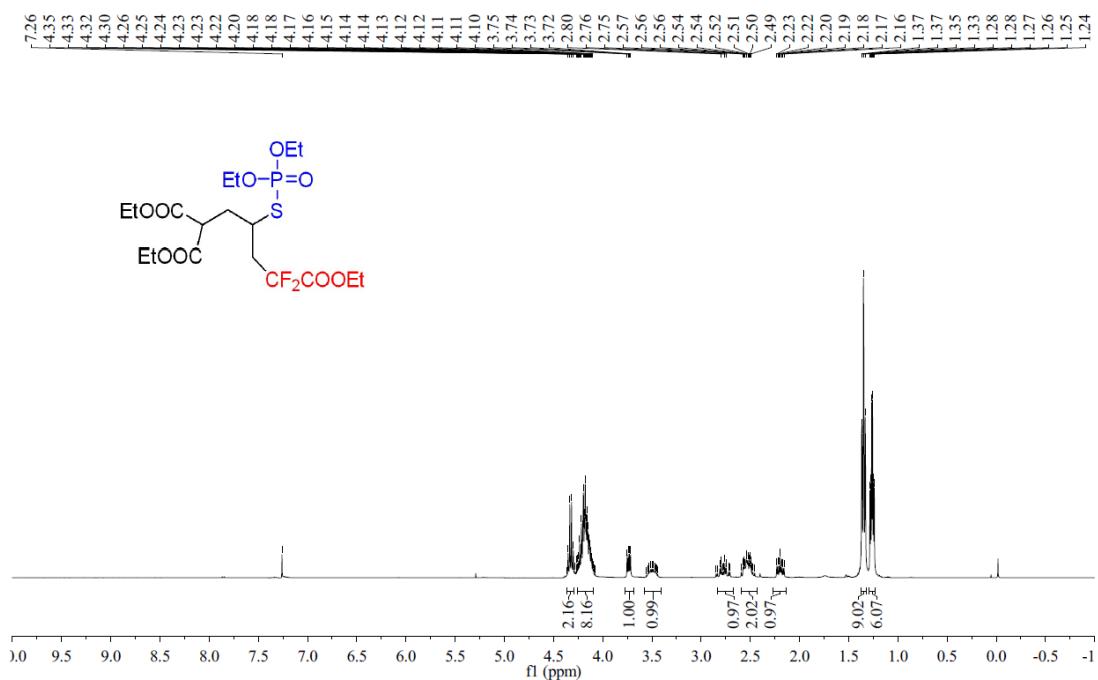
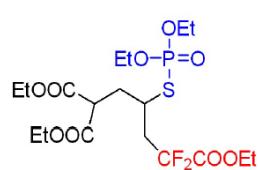
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **5a** in  $\text{CDCl}_3$



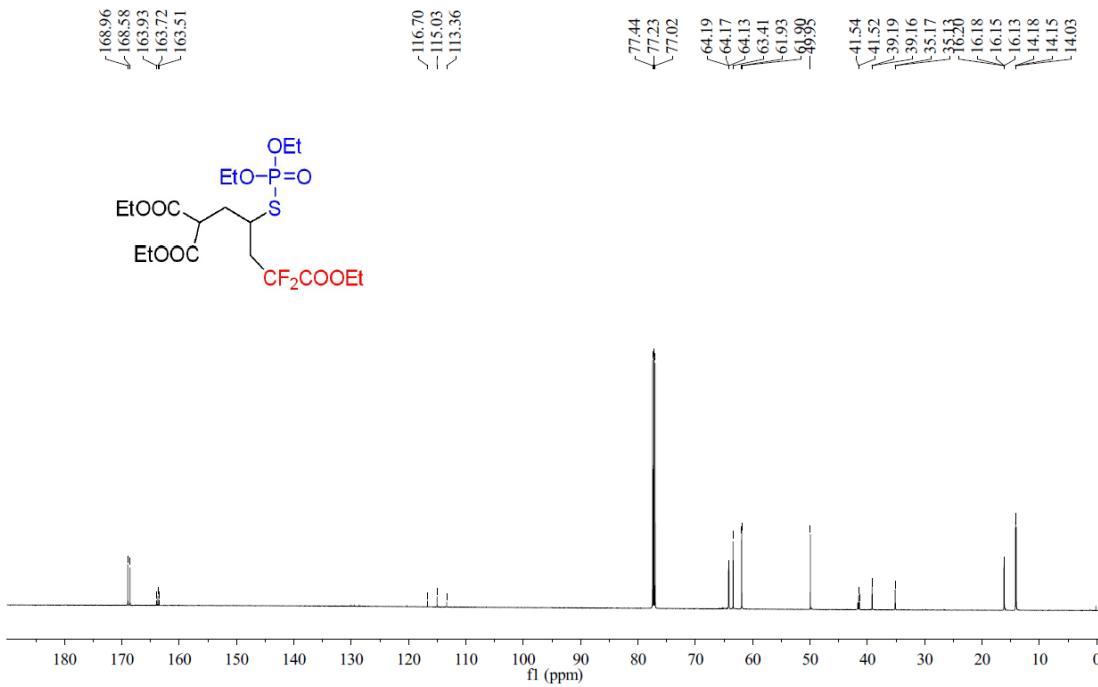
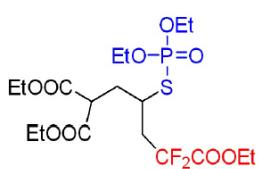
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **5a** in  $\text{CDCl}_3$



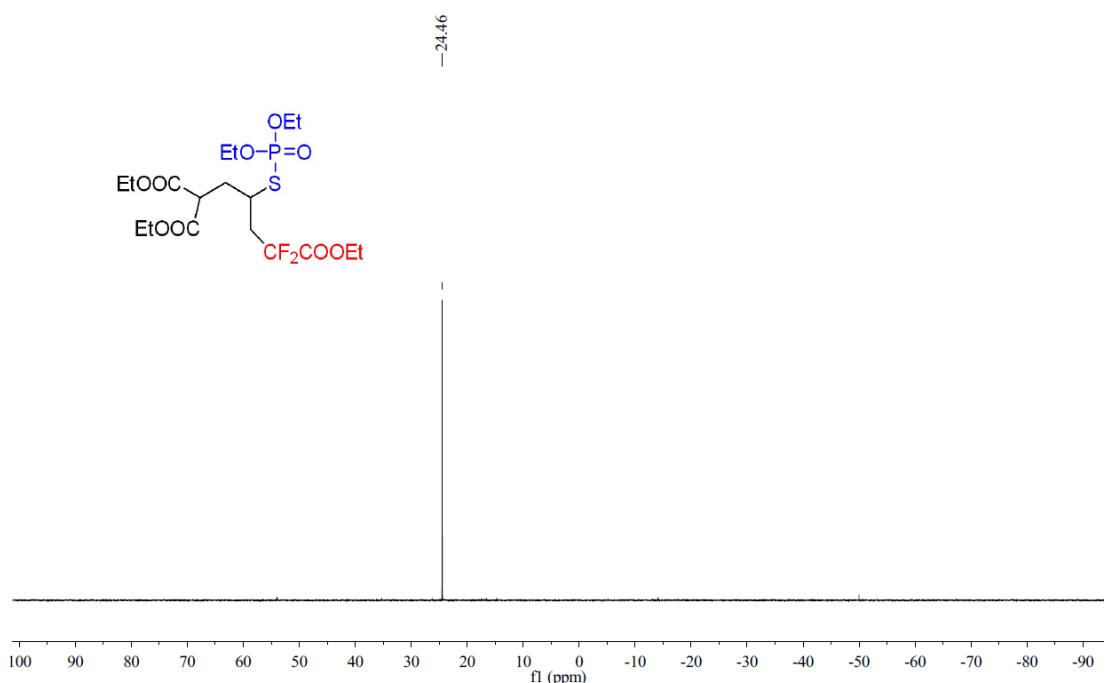
<sup>1</sup>H NMR (400 MHz) Spectrum of **5b** in CDCl<sub>3</sub>



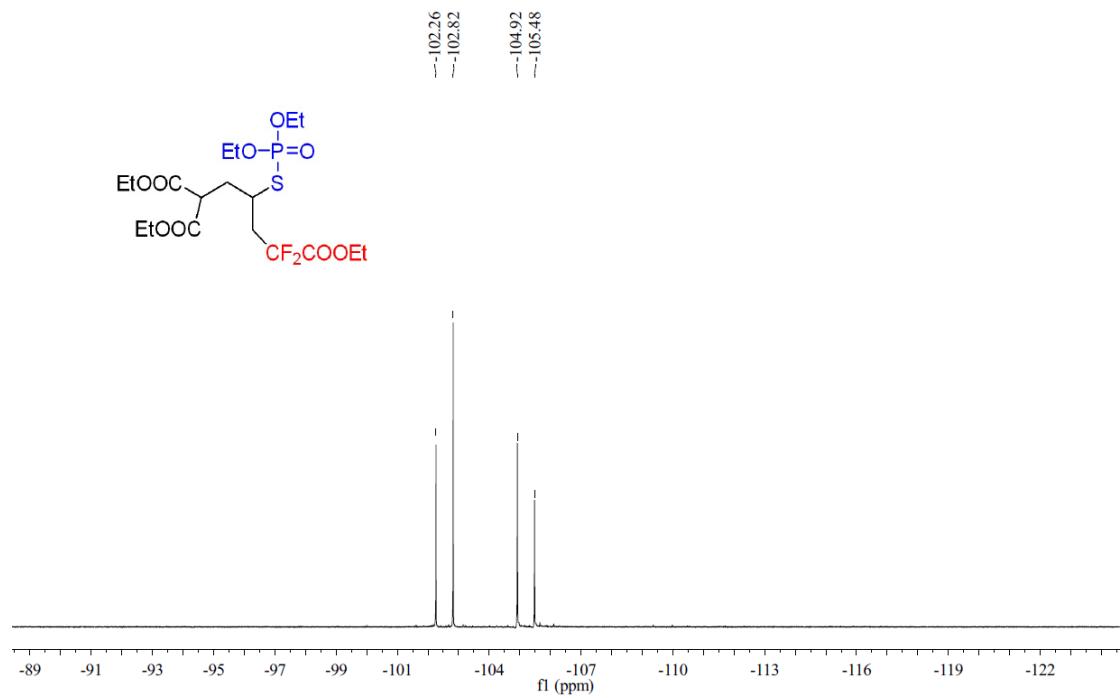
<sup>13</sup>C NMR (151 MHz) Spectrum of **5b** in CDCl<sub>3</sub>



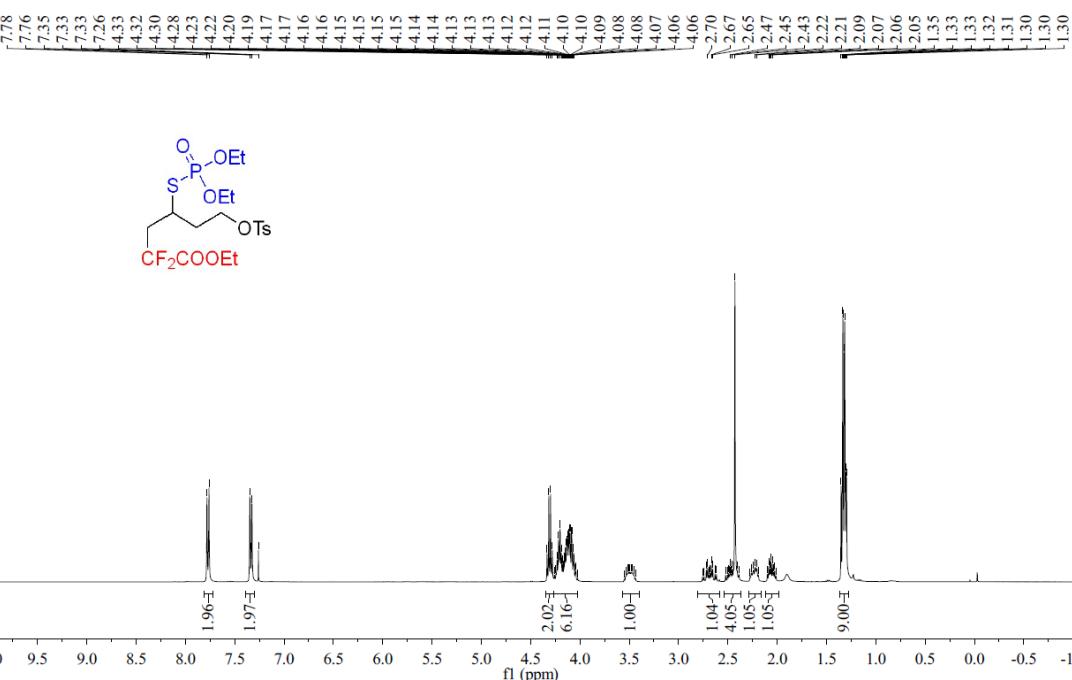
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **5b** in  $\text{CDCl}_3$



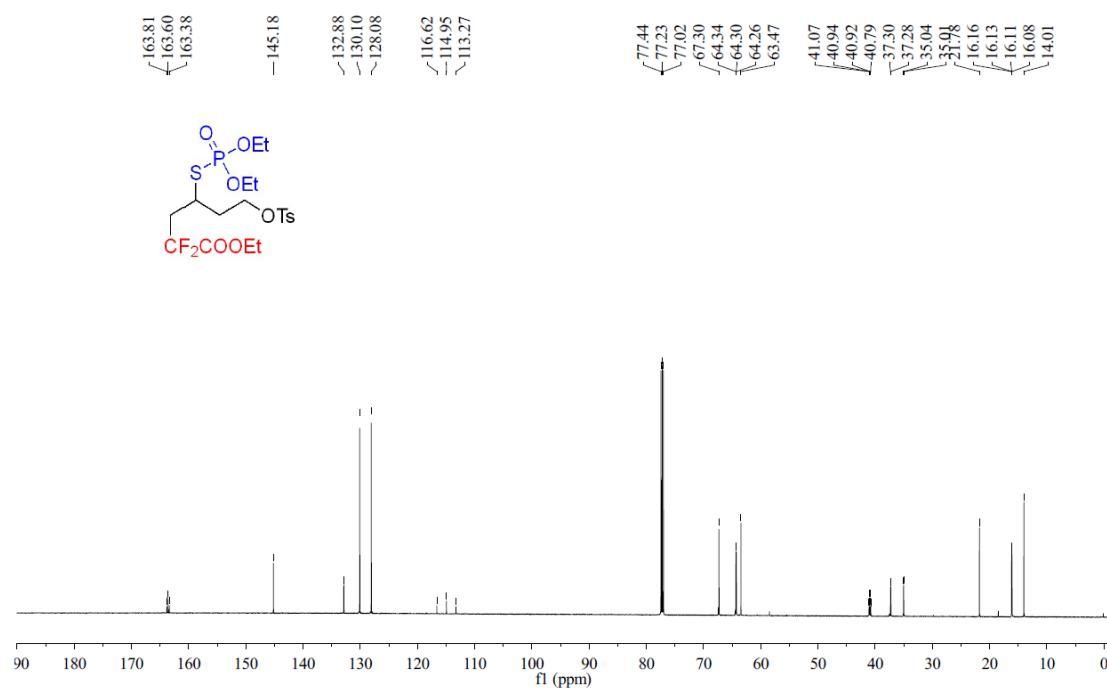
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **5b** in  $\text{CDCl}_3$



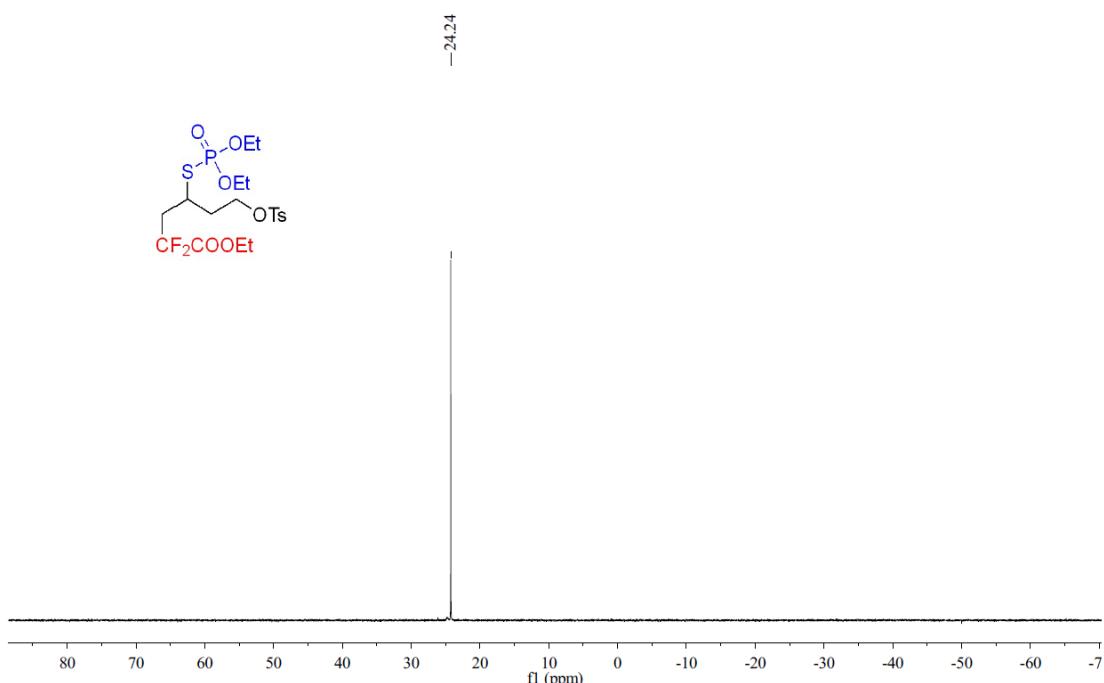
<sup>1</sup>H NMR (400 MHz) Spectrum of **5c** in CDCl<sub>3</sub>



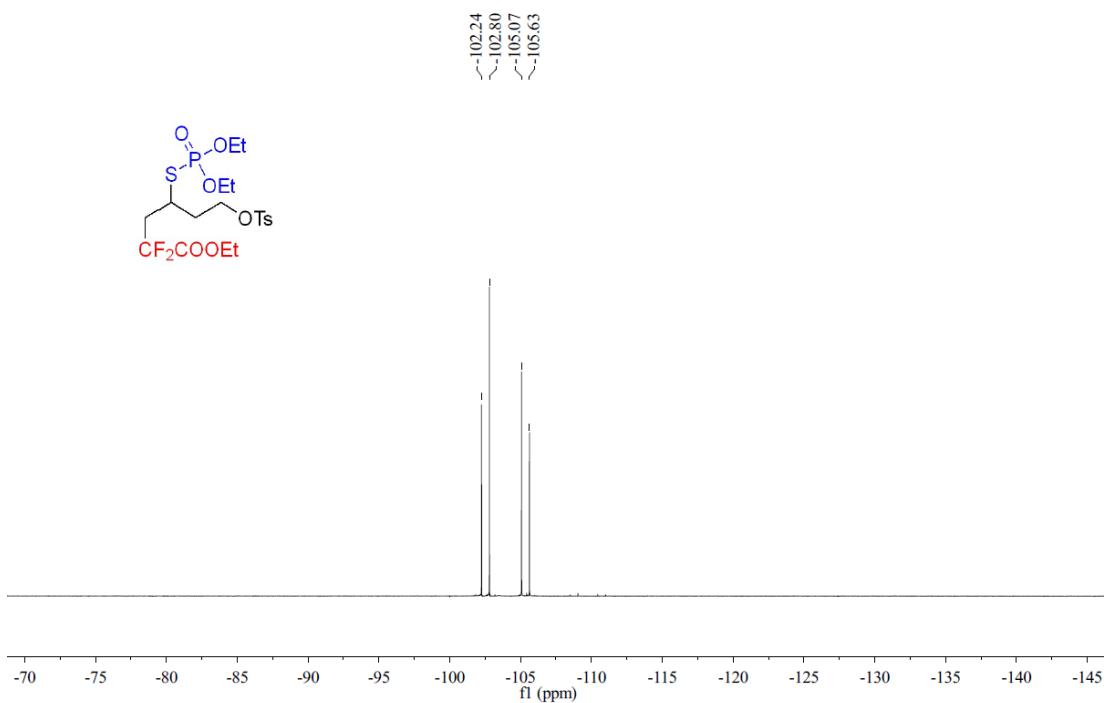
<sup>13</sup>C NMR (151 MHz) Spectrum of **5c** in CDCl<sub>3</sub>



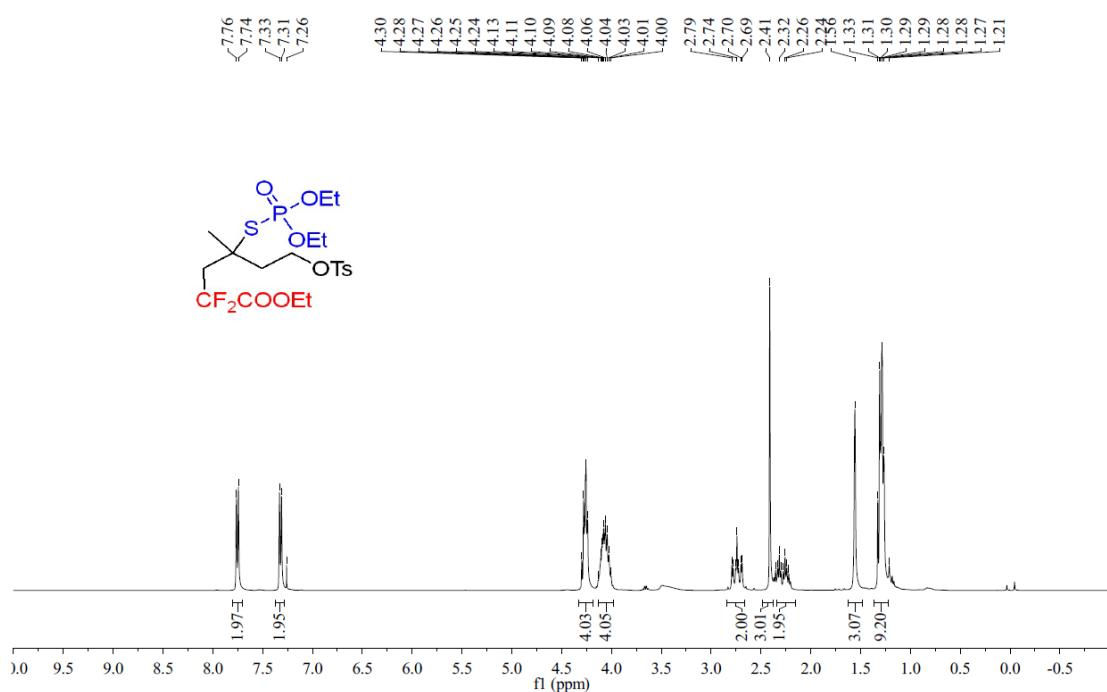
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **5c** in  $\text{CDCl}_3$



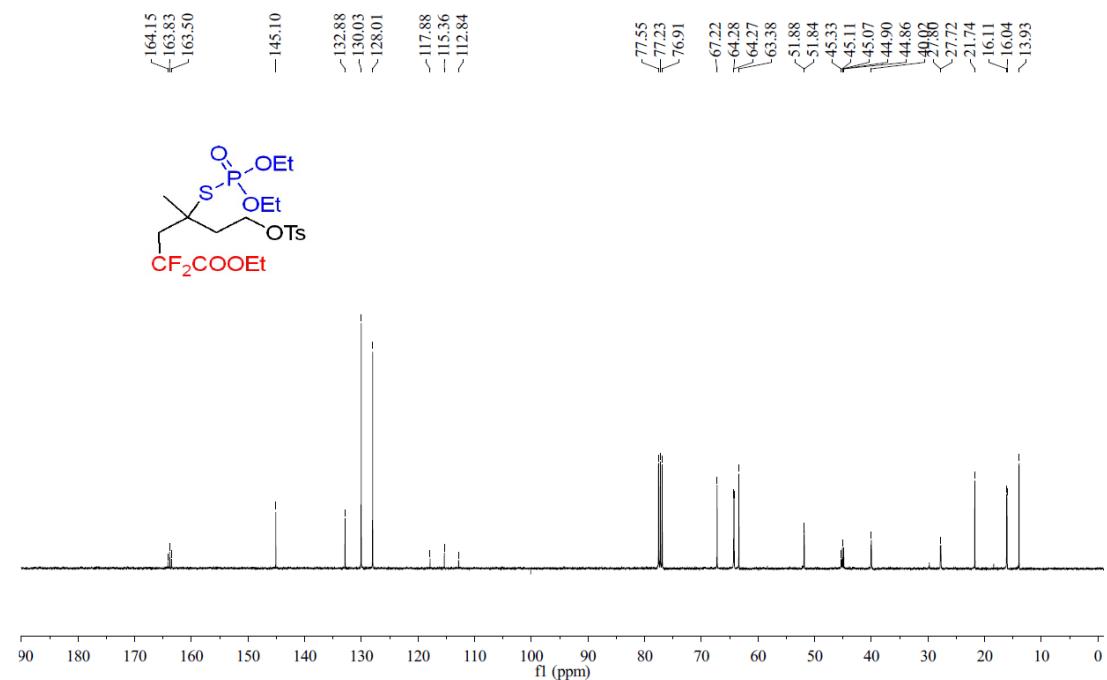
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **5c** in  $\text{CDCl}_3$



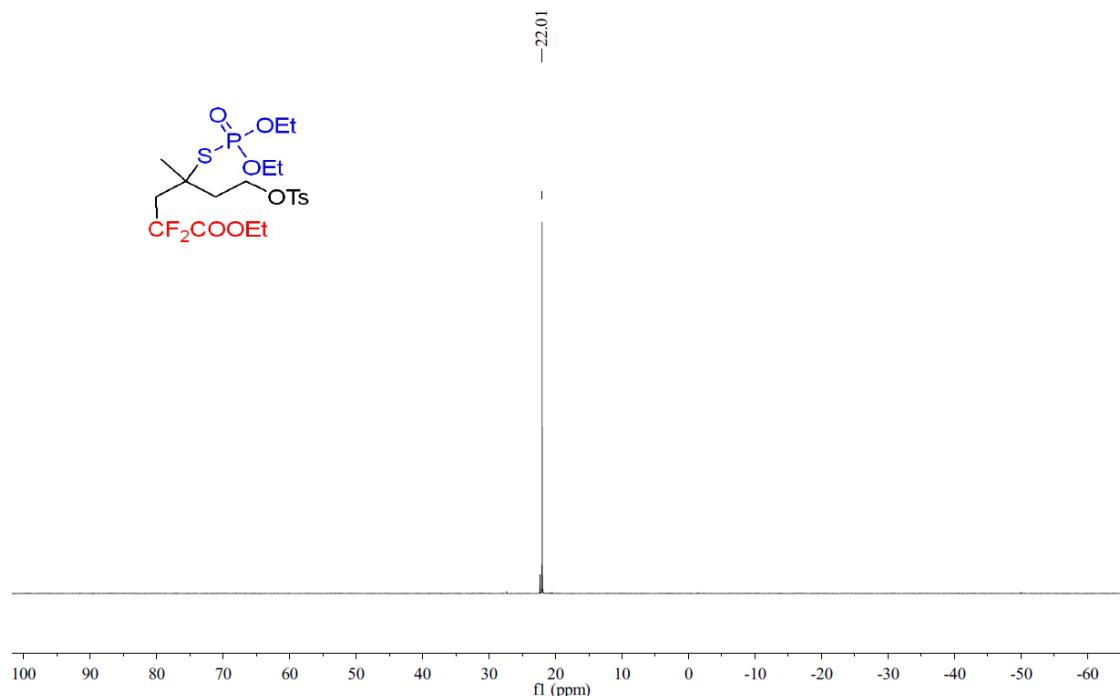
<sup>1</sup>H NMR (400 MHz) Spectrum of **5d** in CDCl<sub>3</sub>



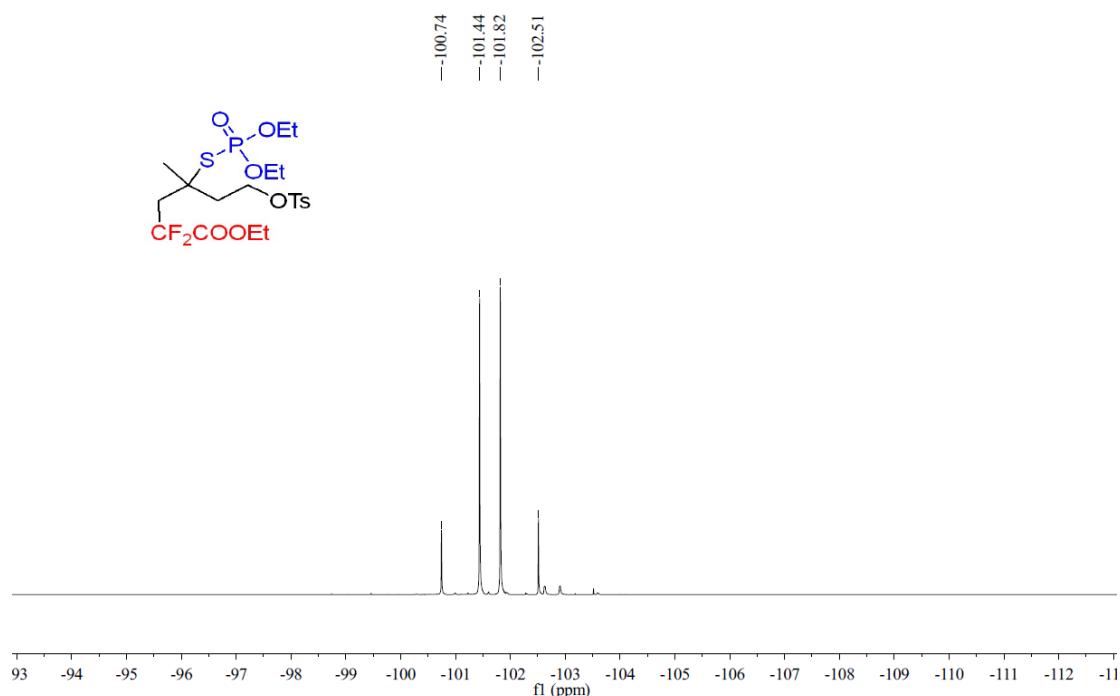
<sup>13</sup>C NMR (151 MHz) Spectrum of **5d** in CDCl<sub>3</sub>



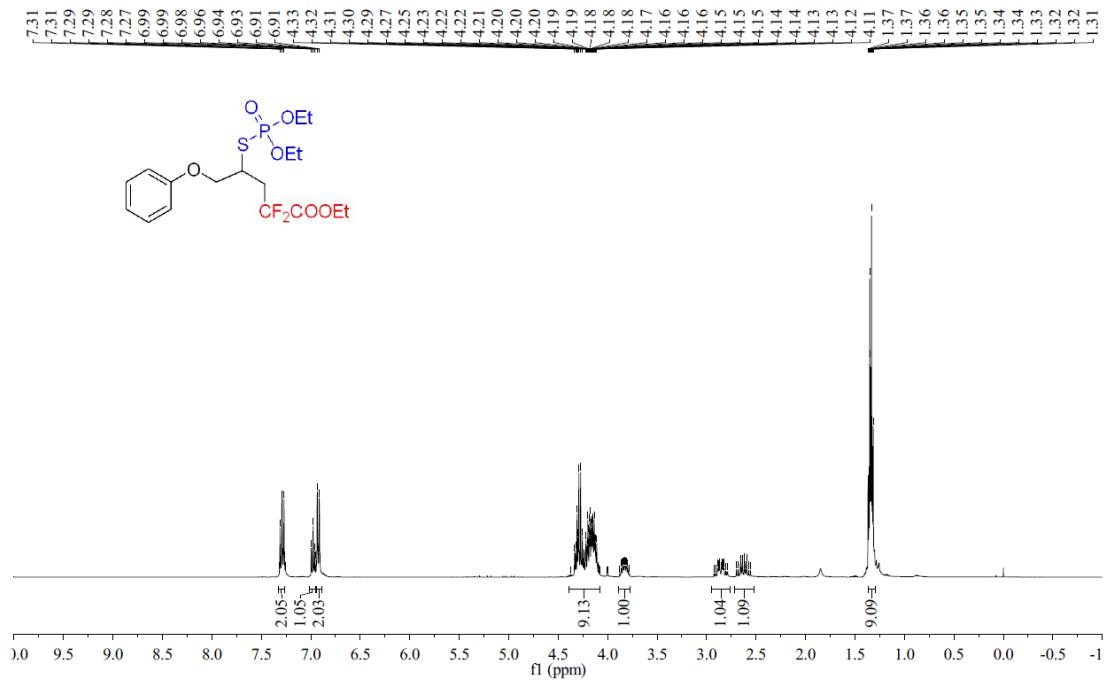
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **5d** in  $\text{CDCl}_3$



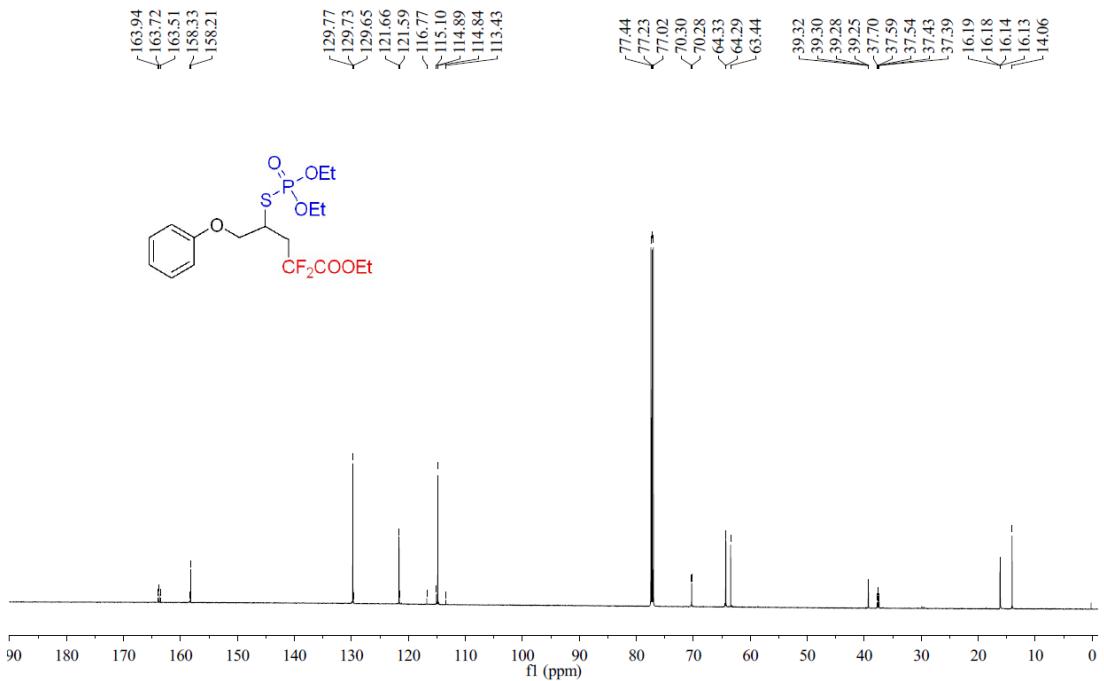
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **5d** in  $\text{CDCl}_3$



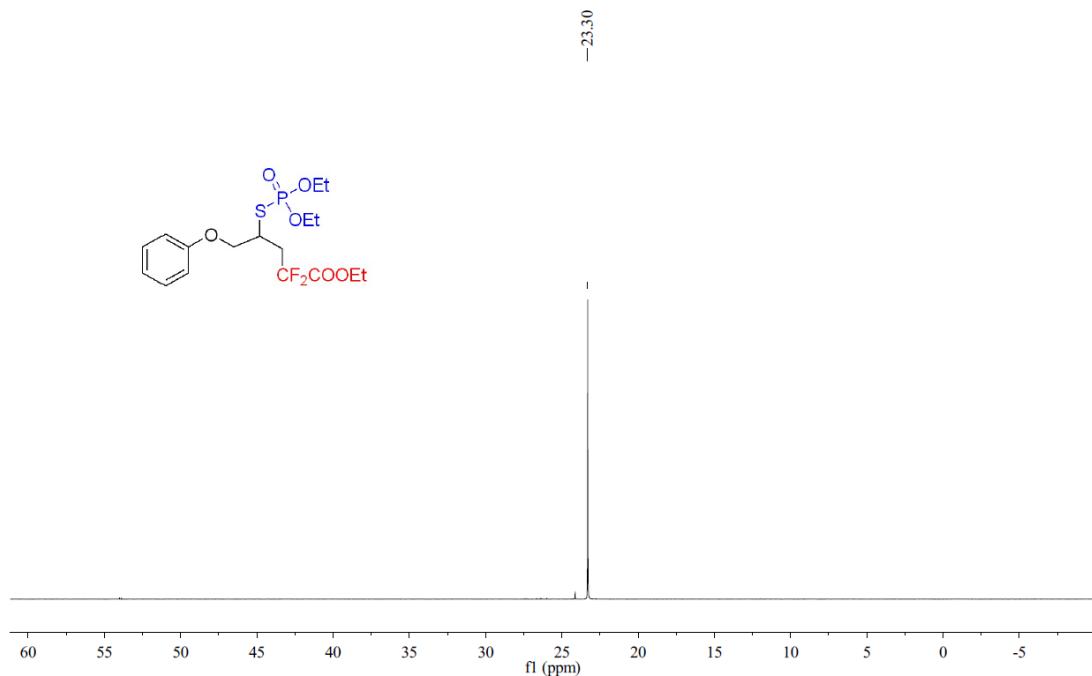
<sup>1</sup>H NMR (400 MHz) Spectrum of **5e** in CDCl<sub>3</sub>



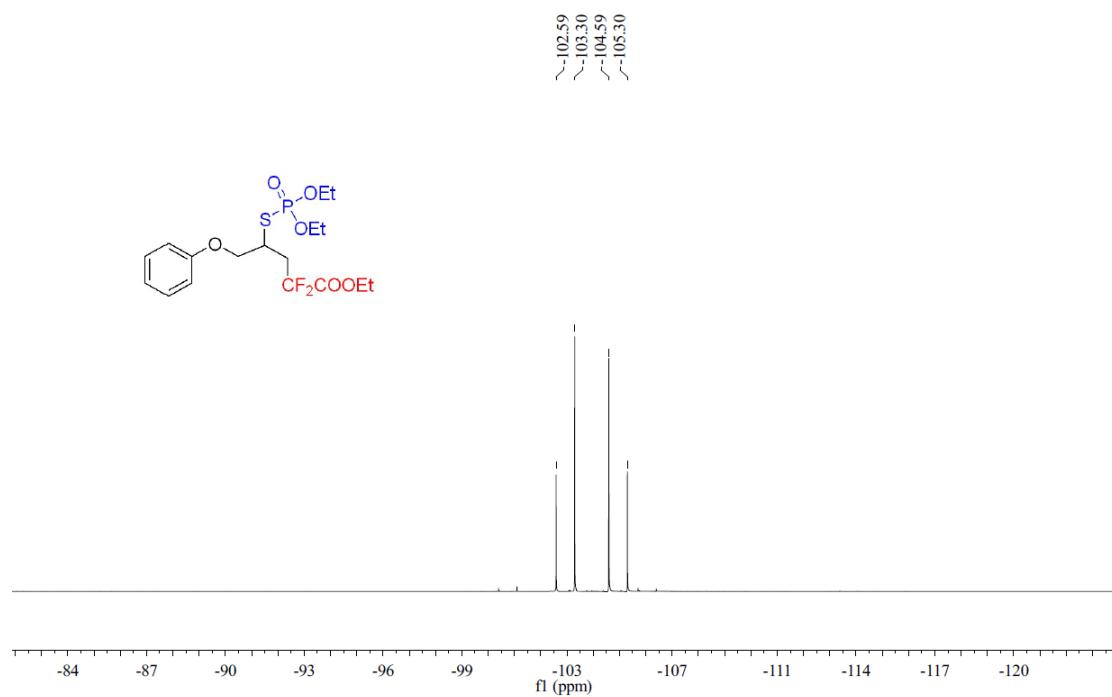
<sup>13</sup>C NMR (151 MHz) Spectrum of **5e** in CDCl<sub>3</sub>



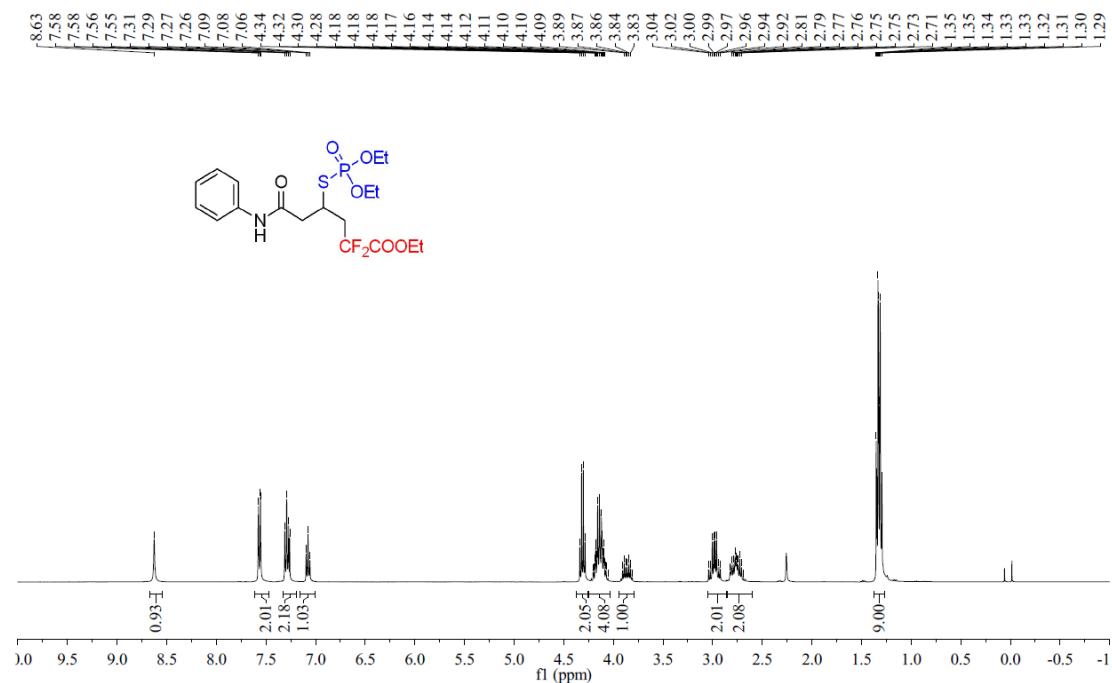
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **5e** in  $\text{CDCl}_3$



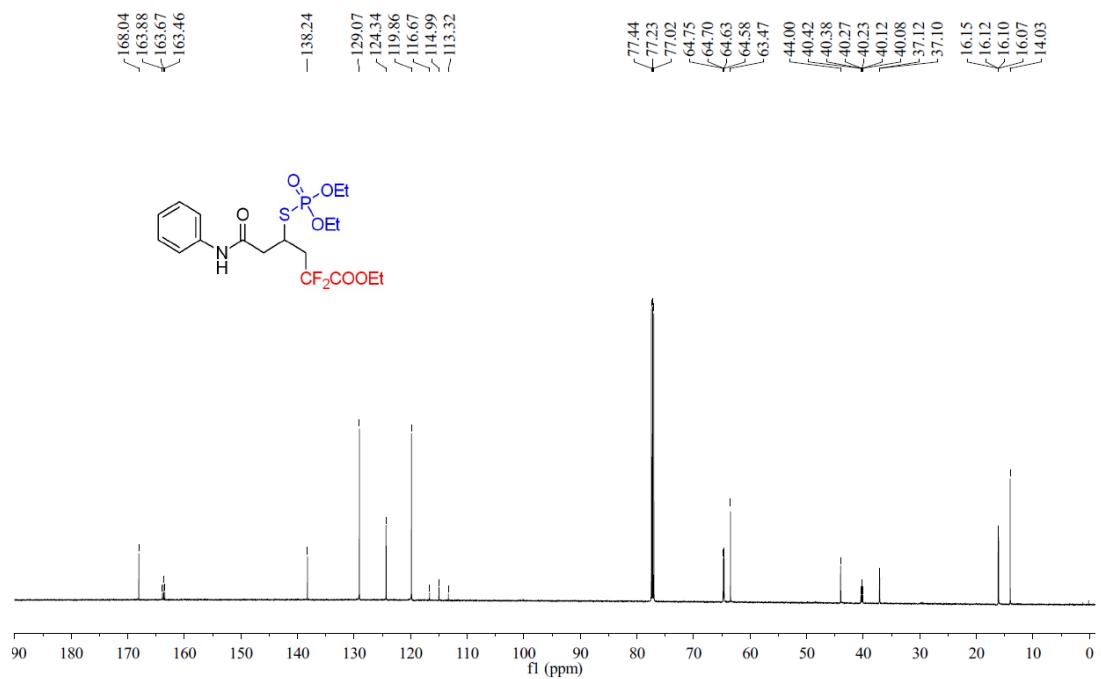
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **5e** in  $\text{CDCl}_3$



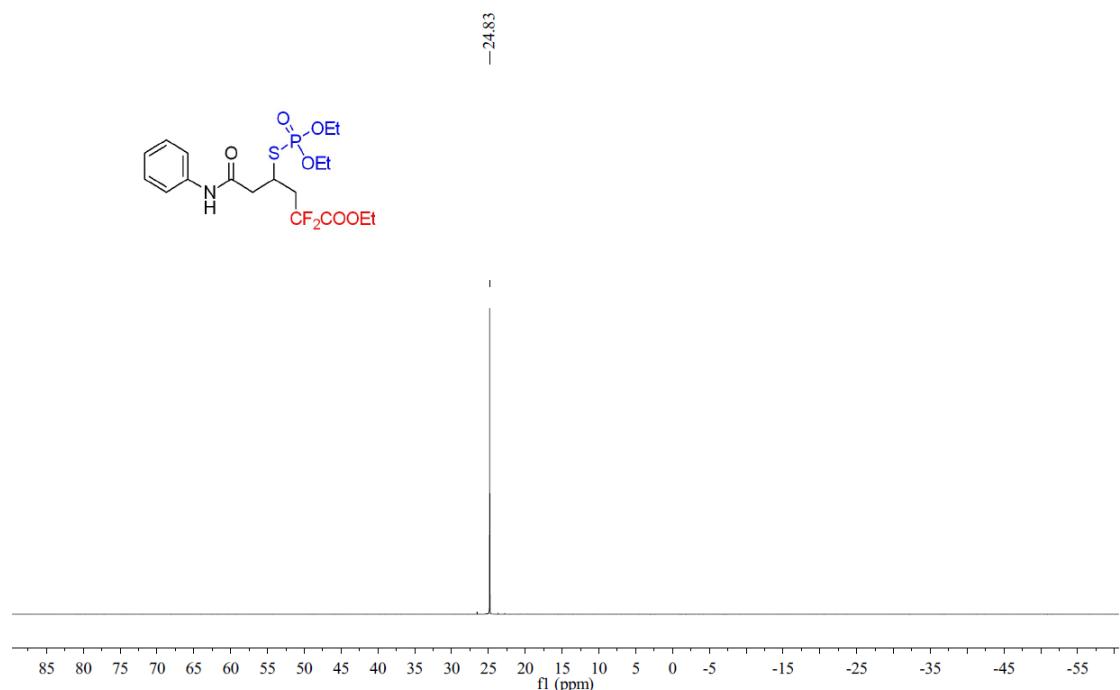
<sup>1</sup>H NMR (400 MHz) Spectrum of **5f** in CDCl<sub>3</sub>



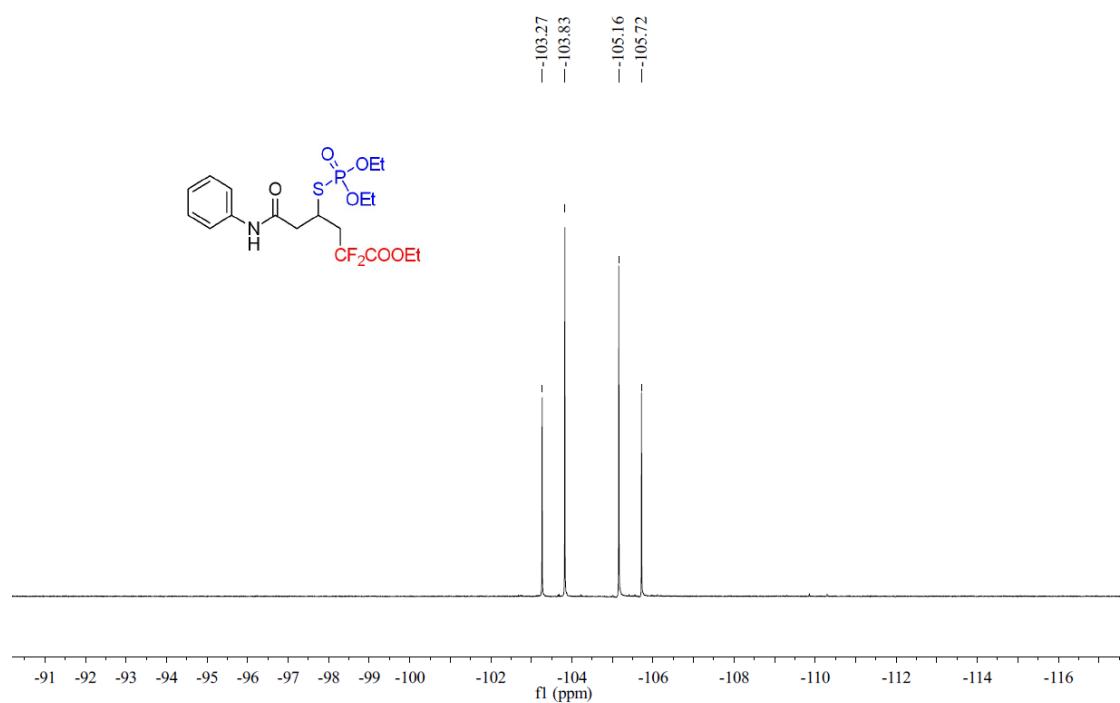
<sup>13</sup>C NMR (151 MHz) Spectrum of **5f** in CDCl<sub>3</sub>



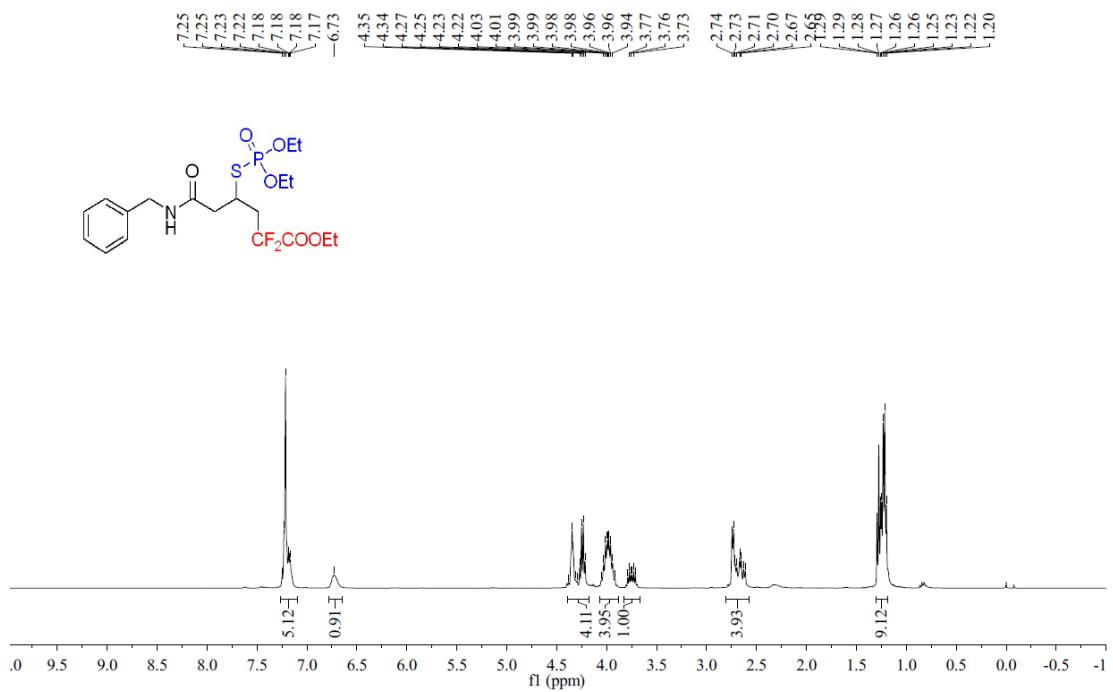
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **5f** in  $\text{CDCl}_3$



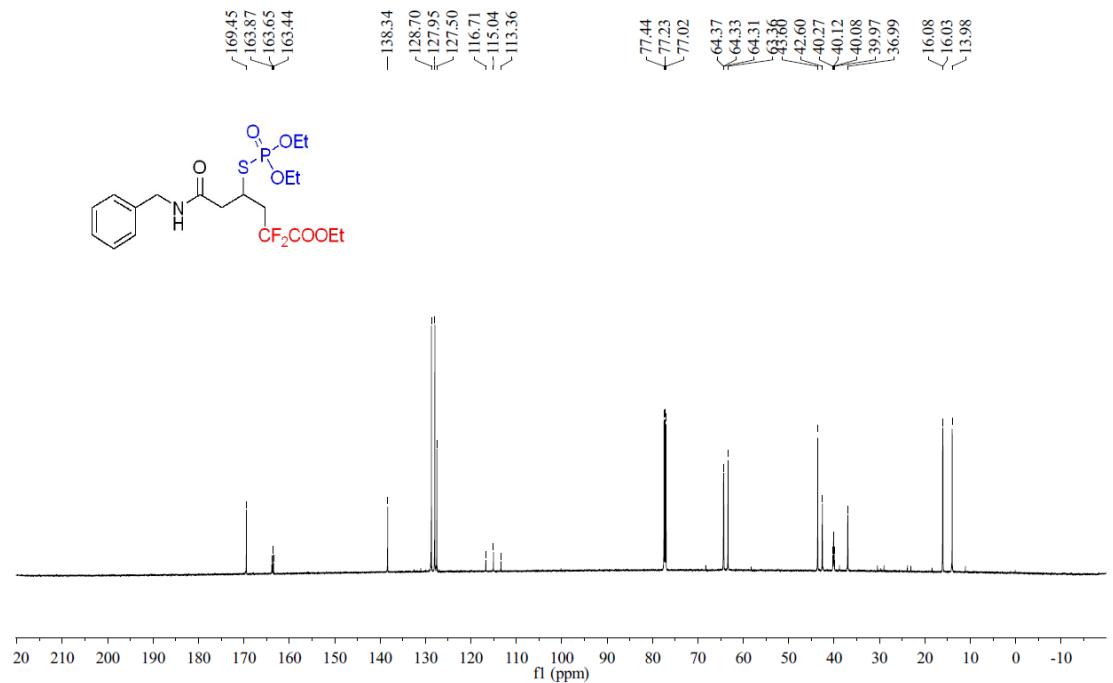
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **5f** in  $\text{CDCl}_3$



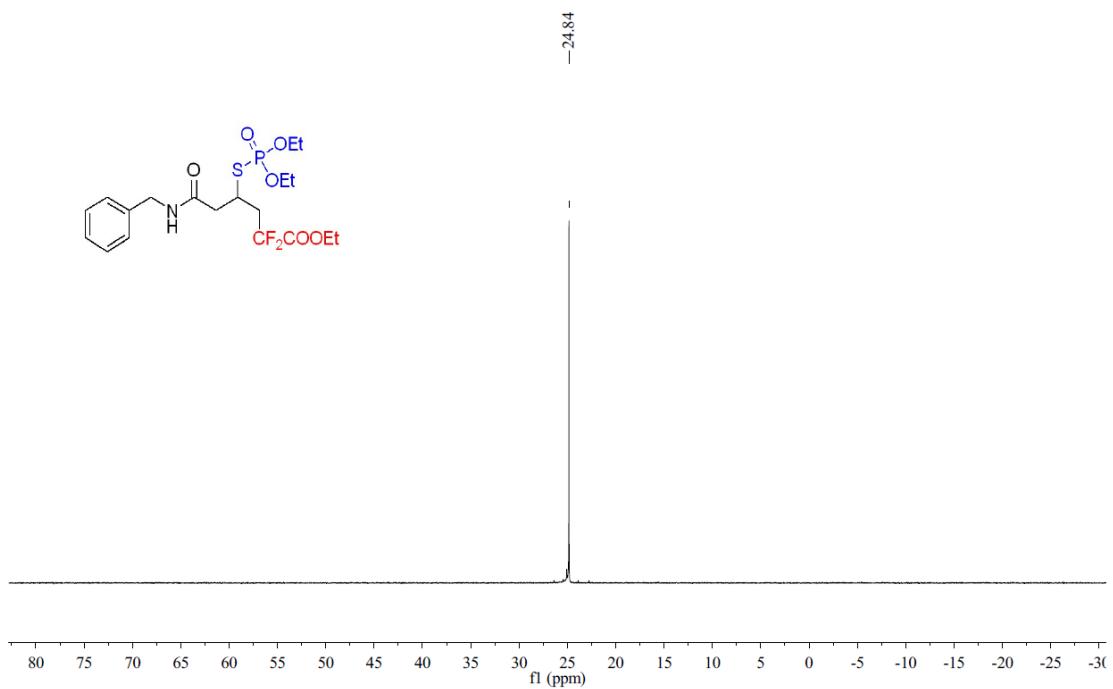
<sup>1</sup>H NMR (400 MHz) Spectrum of **5g** in CDCl<sub>3</sub>



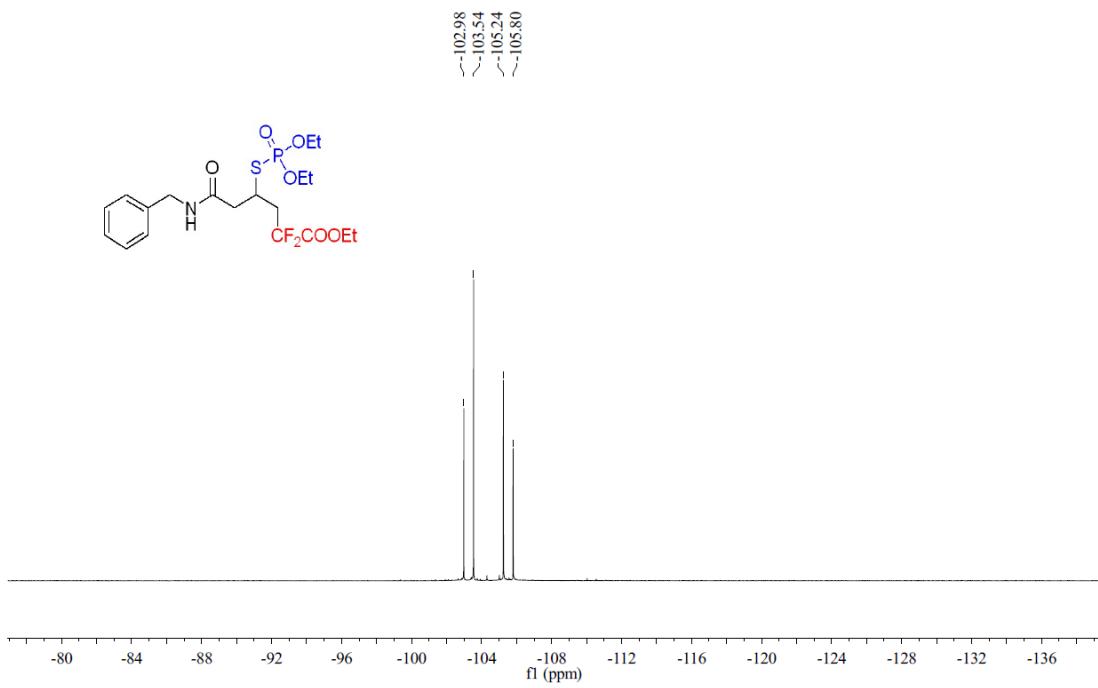
<sup>13</sup>C NMR (151 MHz) Spectrum of **5g** in CDCl<sub>3</sub>



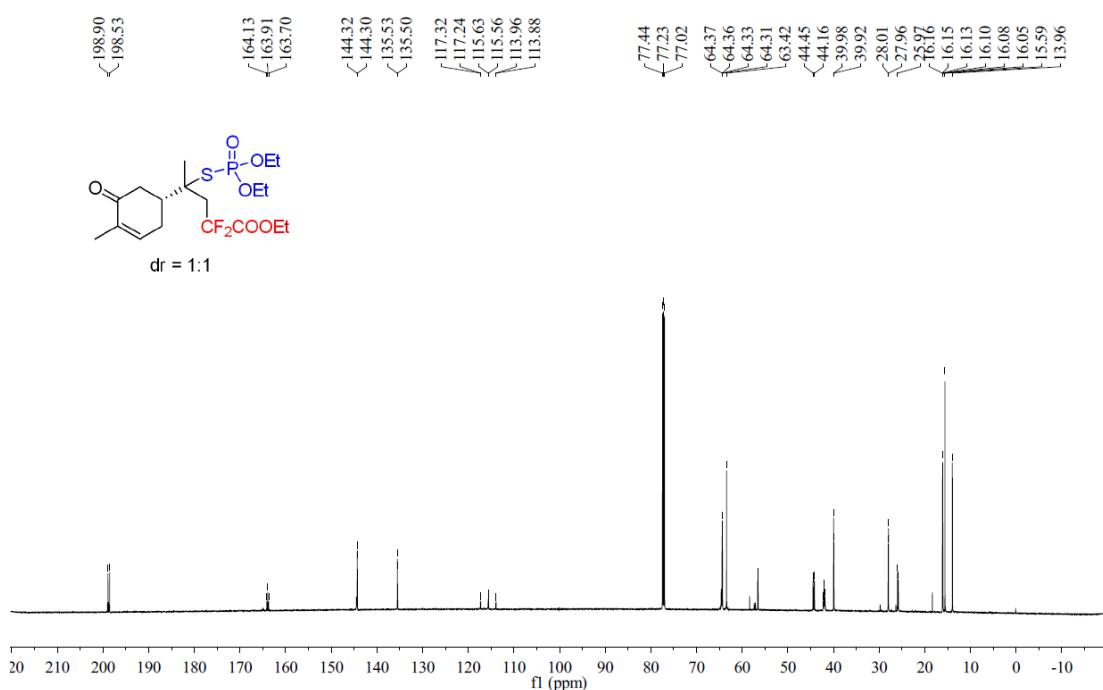
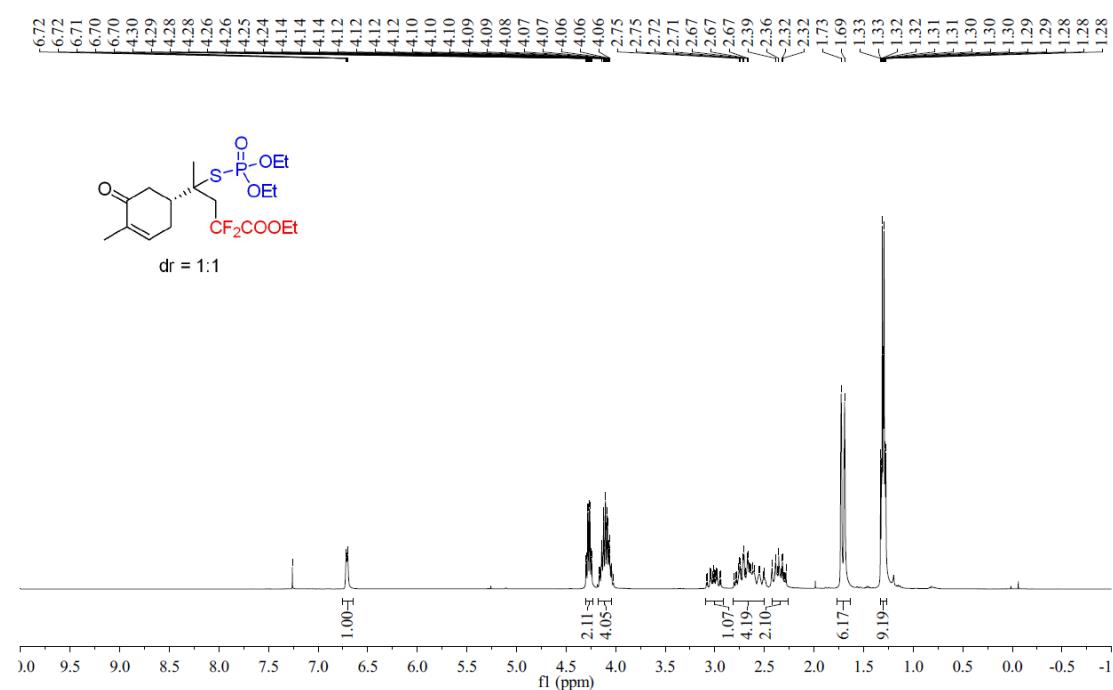
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **5g** in  $\text{CDCl}_3$



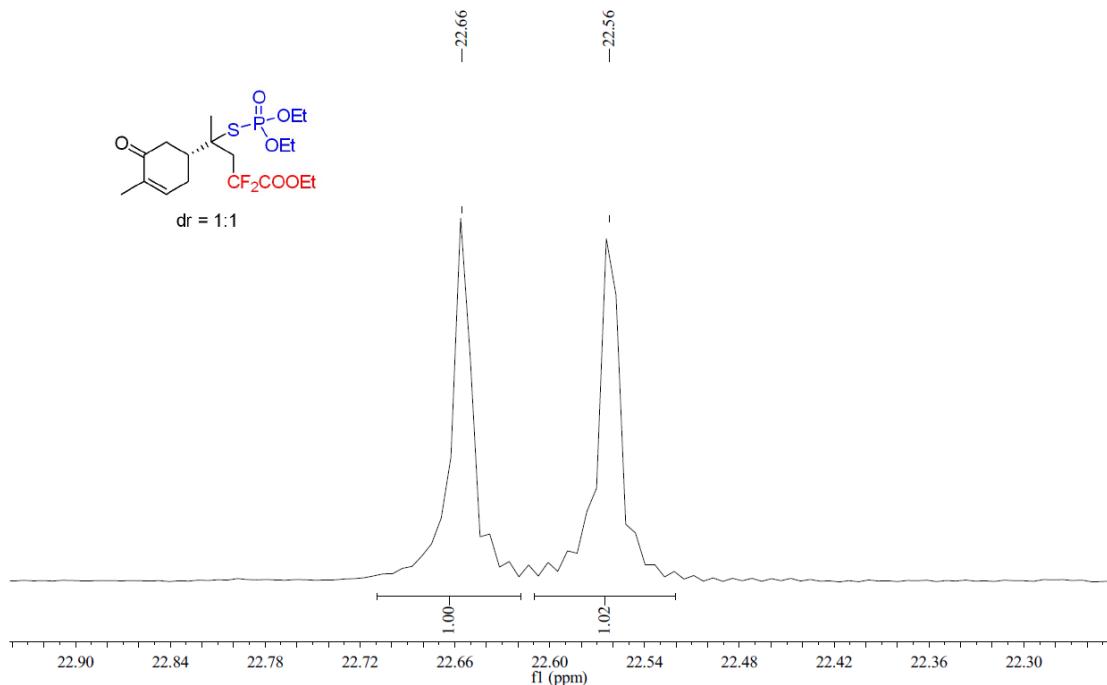
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **5g** in  $\text{CDCl}_3$



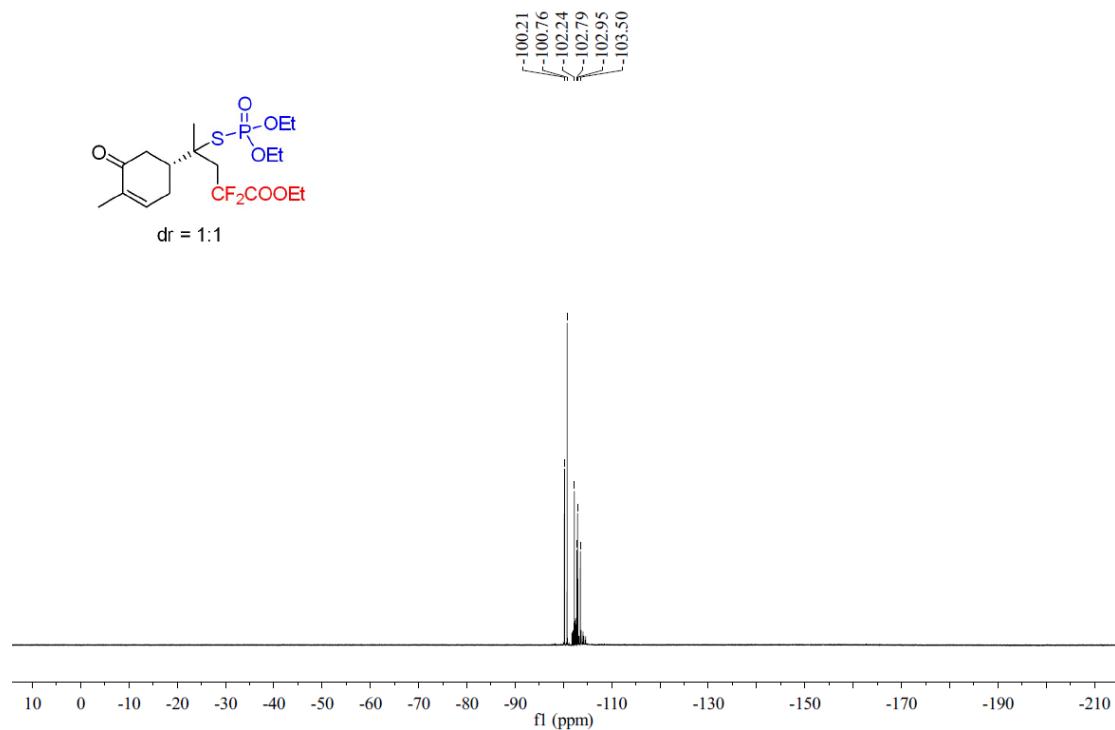
<sup>1</sup>H NMR (400 MHz) Spectrum of **5h** in CDCl<sub>3</sub>



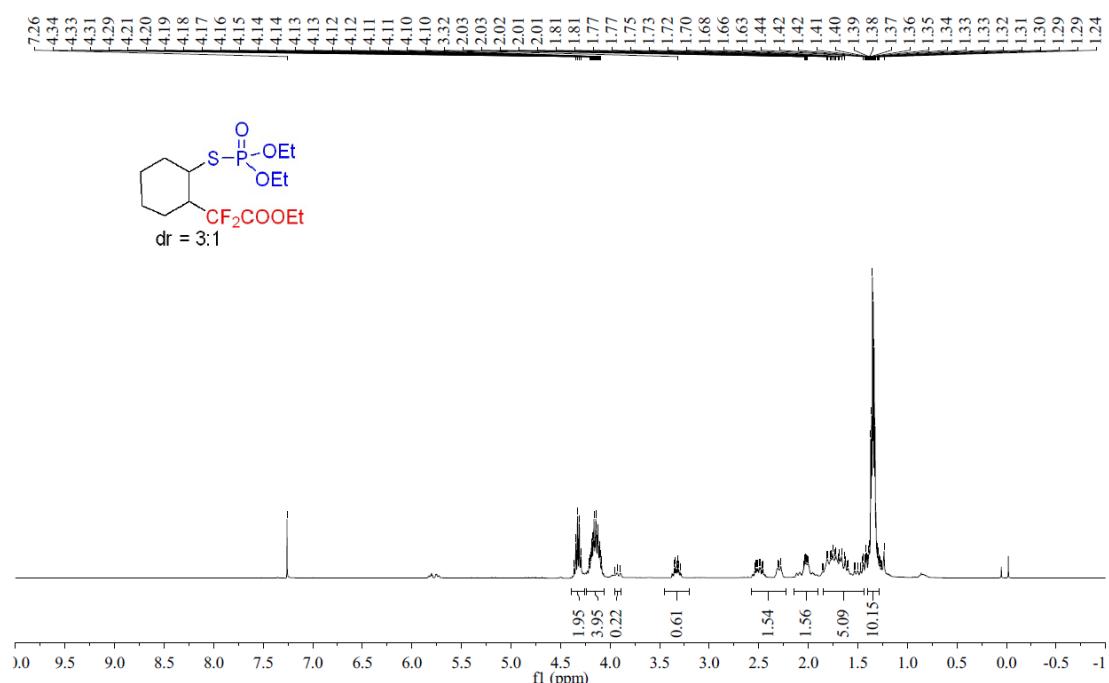
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **5h** in  $\text{CDCl}_3$



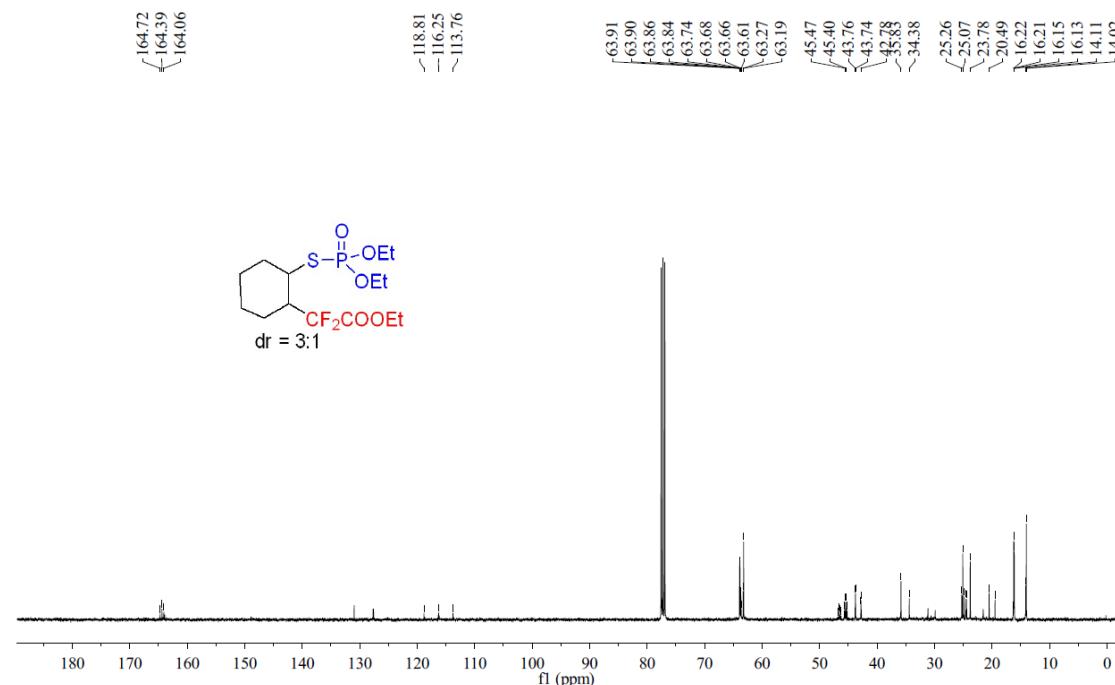
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **5h** in  $\text{CDCl}_3$



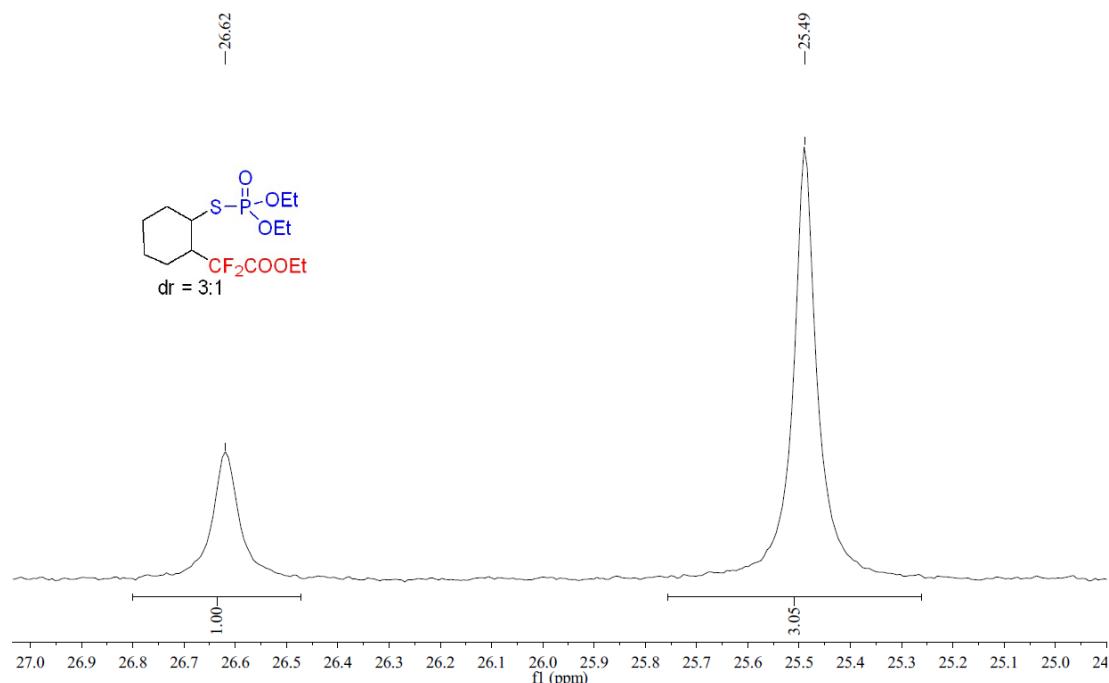
<sup>1</sup>H NMR (400 MHz) Spectrum of **5i** in CDCl<sub>3</sub>



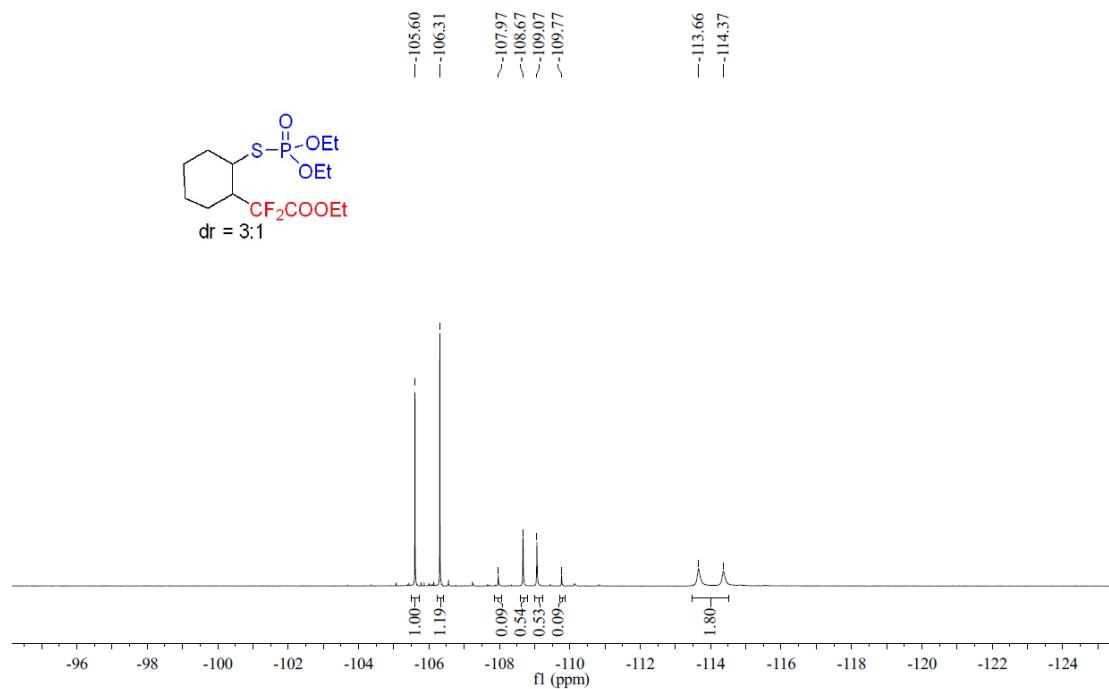
<sup>13</sup>C NMR (151 MHz) Spectrum of **5i** in CDCl<sub>3</sub>



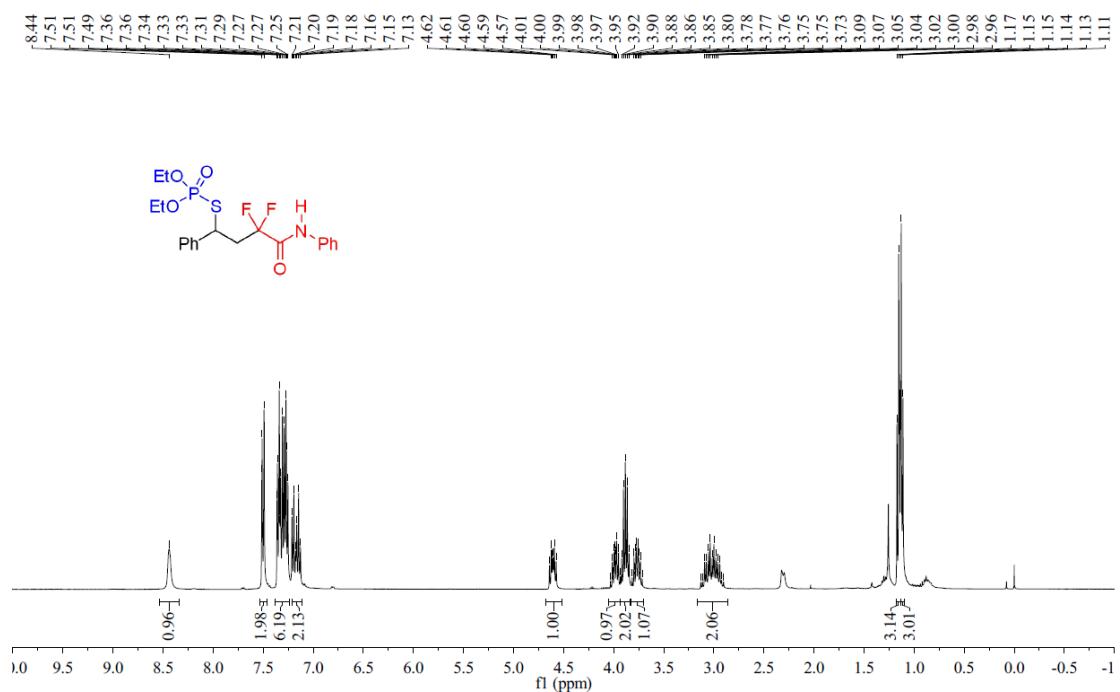
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **5i** in  $\text{CDCl}_3$



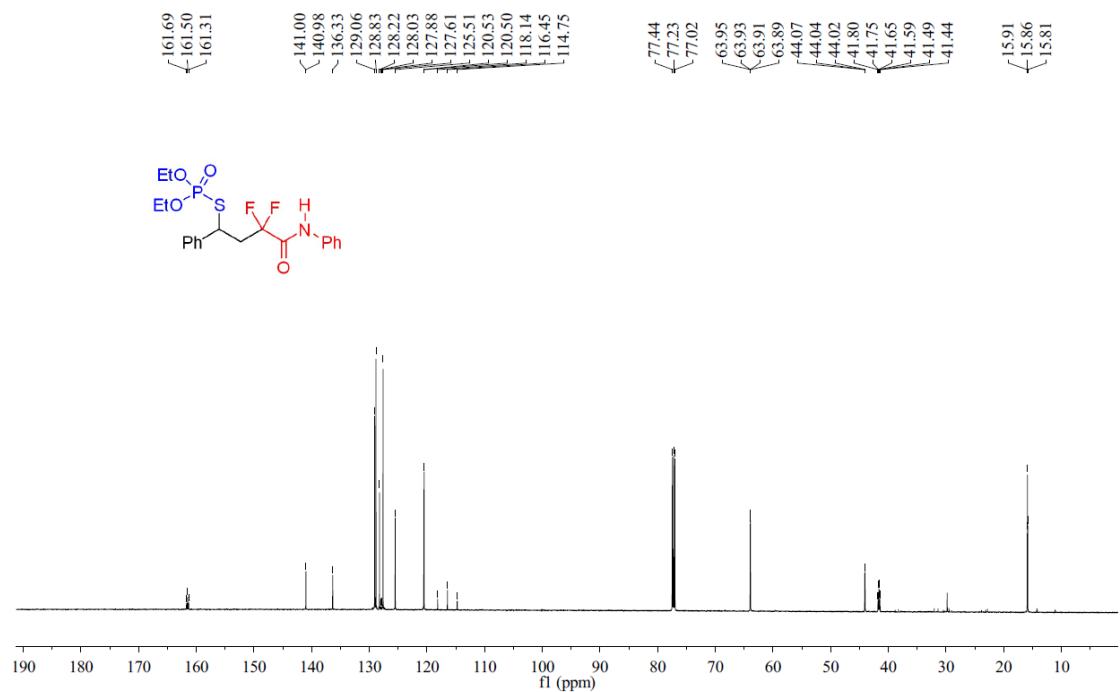
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **5i** in  $\text{CDCl}_3$



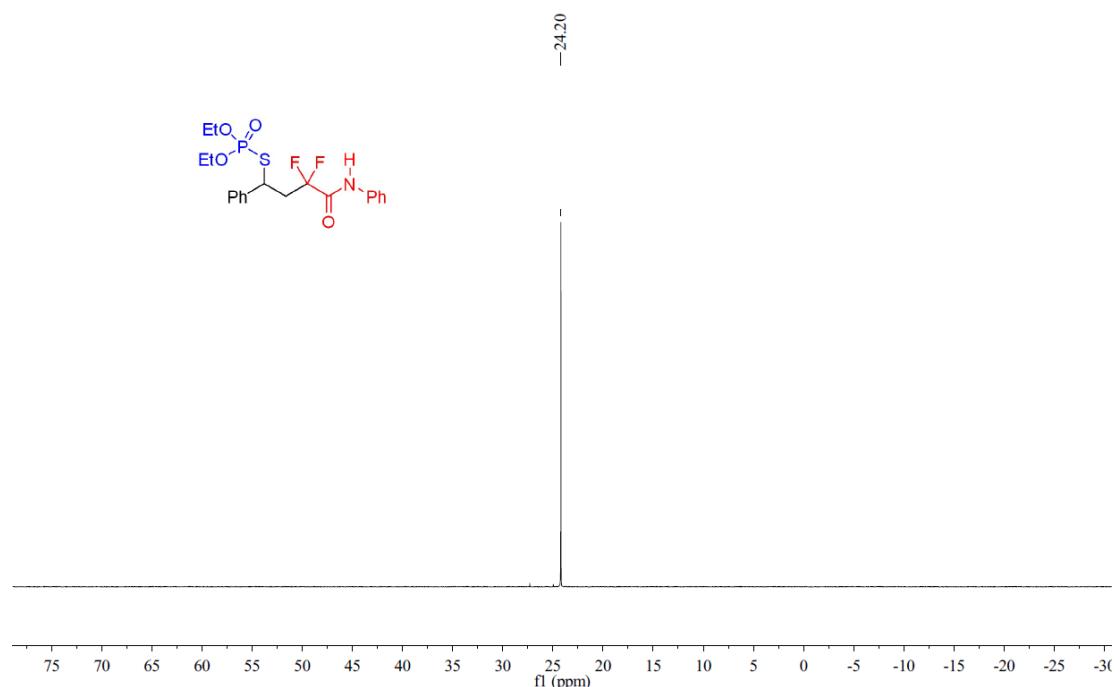
<sup>1</sup>H NMR (400 MHz) Spectrum of **6a** in CDCl<sub>3</sub>



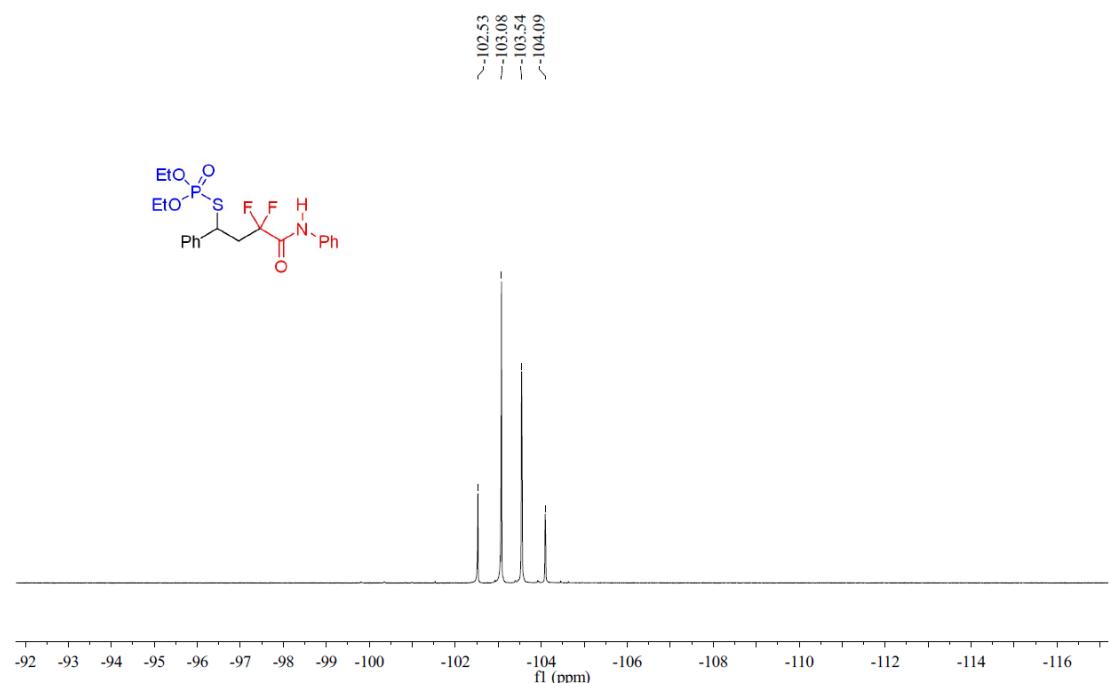
<sup>13</sup>C NMR (151 MHz) Spectrum of **6a** in CDCl<sub>3</sub>



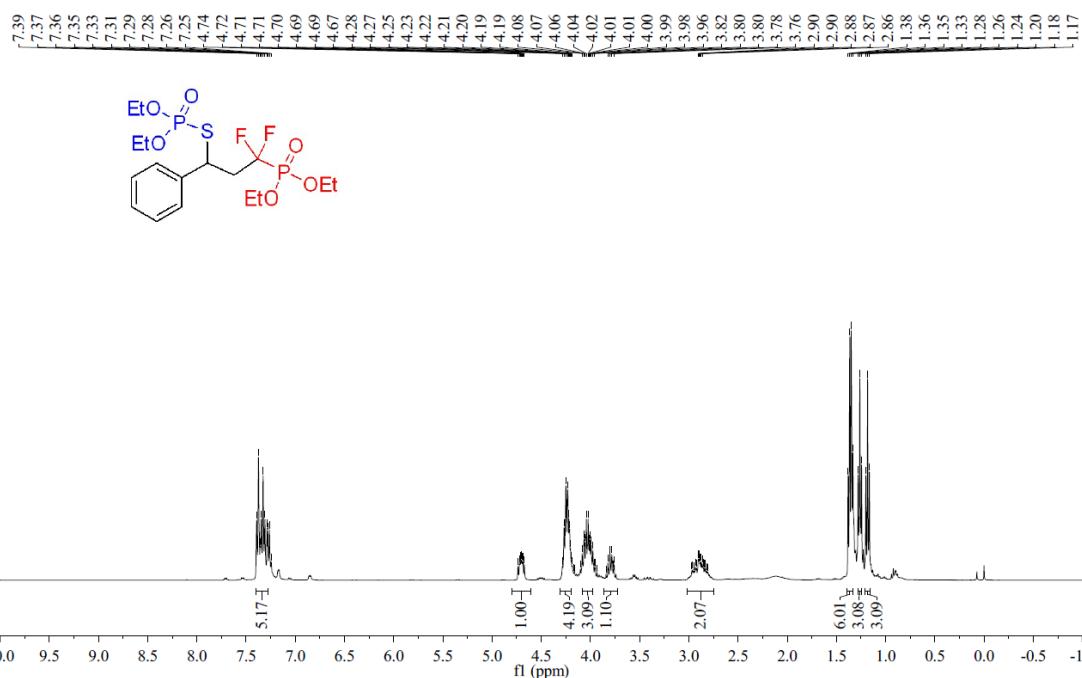
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **6a** in  $\text{CDCl}_3$



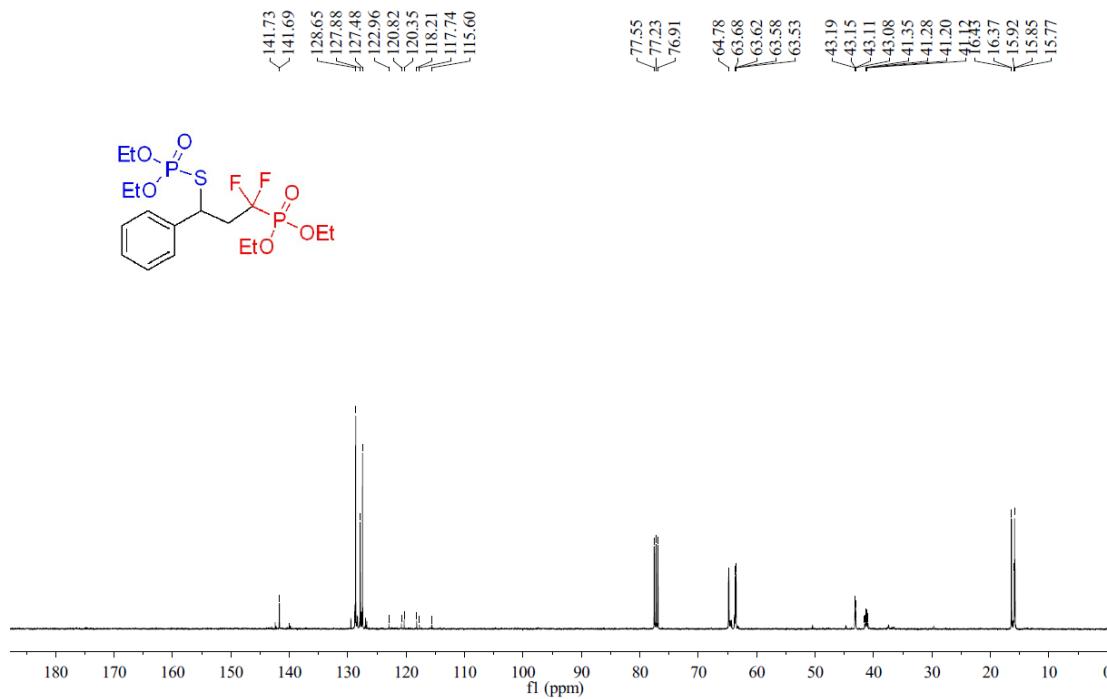
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **6a** in  $\text{CDCl}_3$



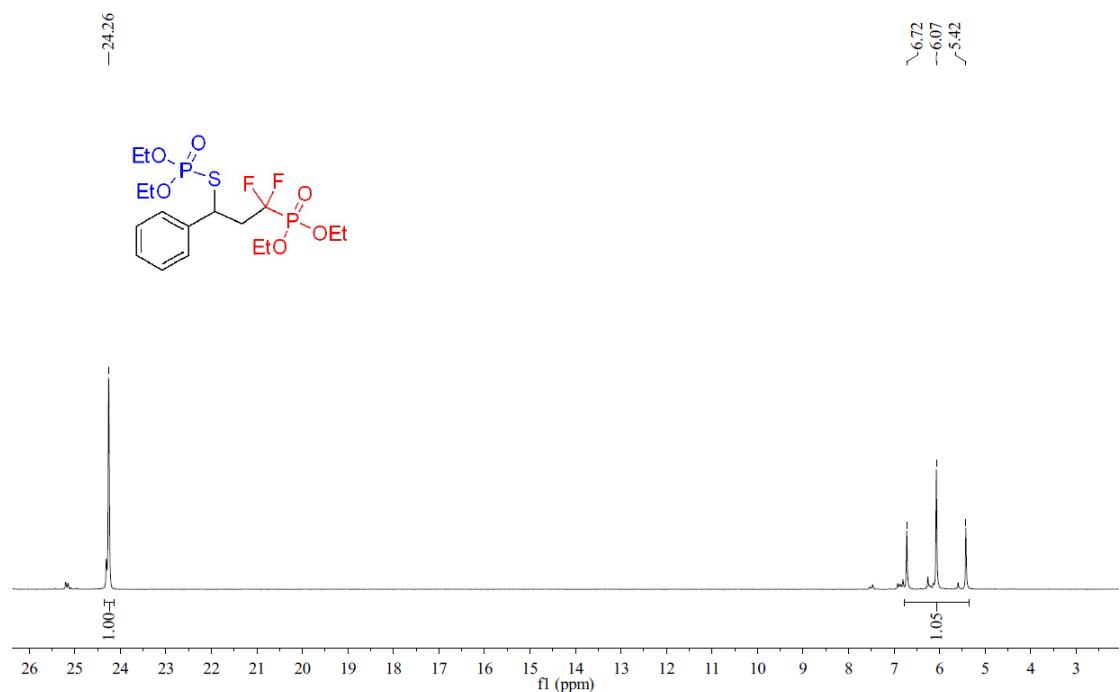
<sup>1</sup>H NMR (400 MHz) Spectrum of **6b** in CDCl<sub>3</sub>



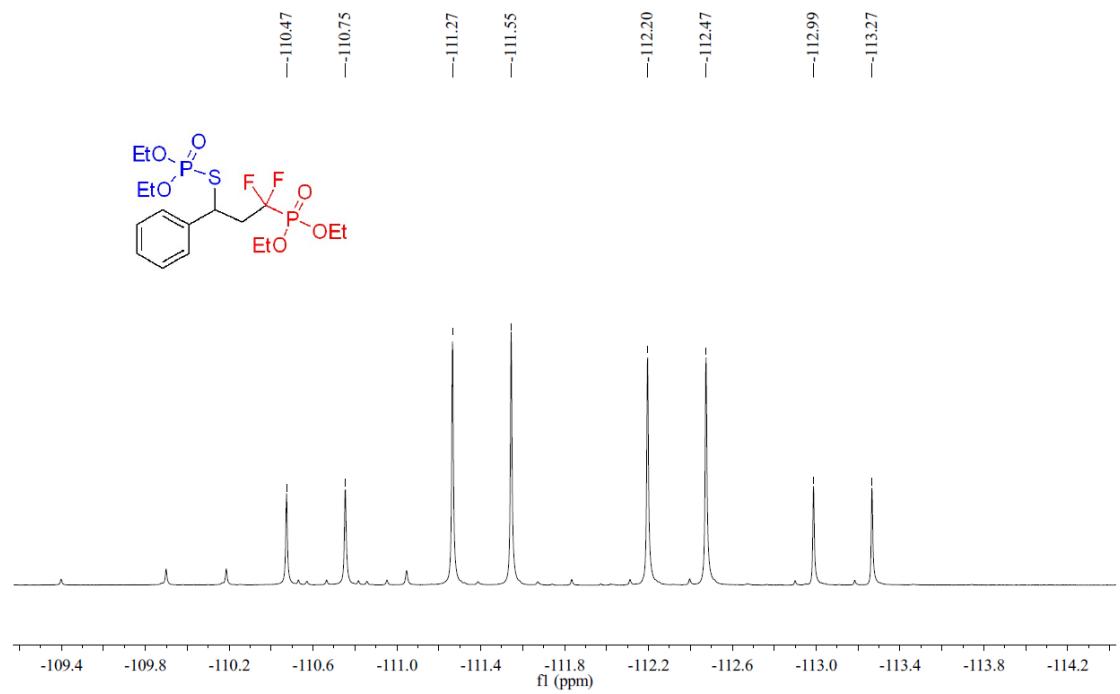
<sup>13</sup>C NMR (151 MHz) Spectrum of **6b** in CDCl<sub>3</sub>



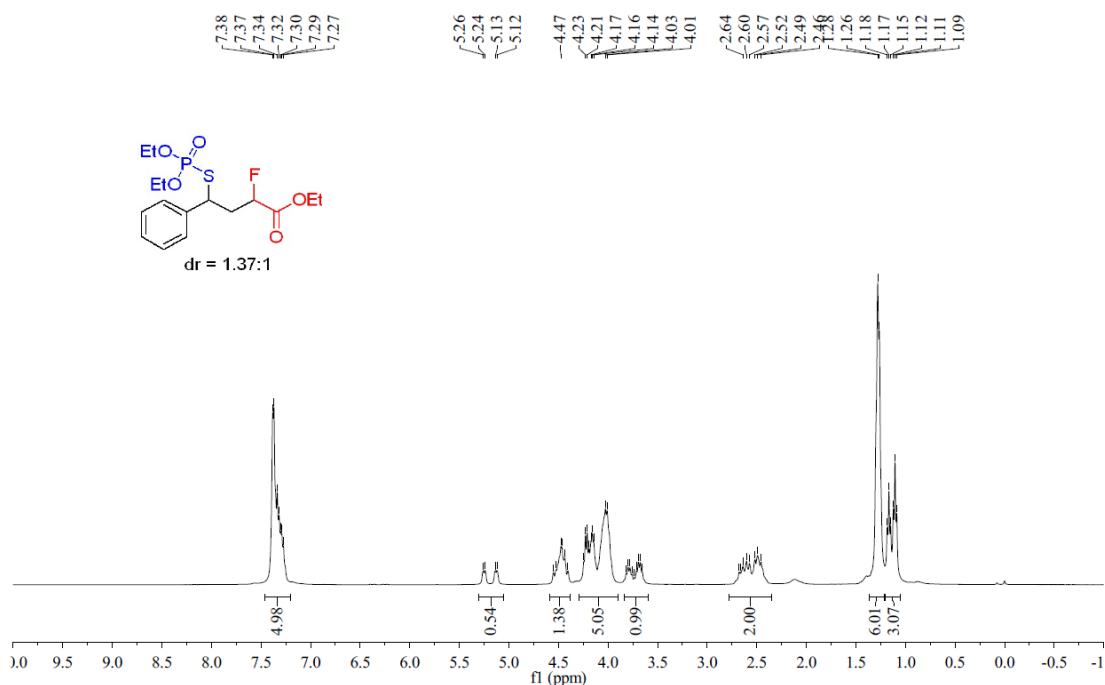
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **6b** in  $\text{CDCl}_3$



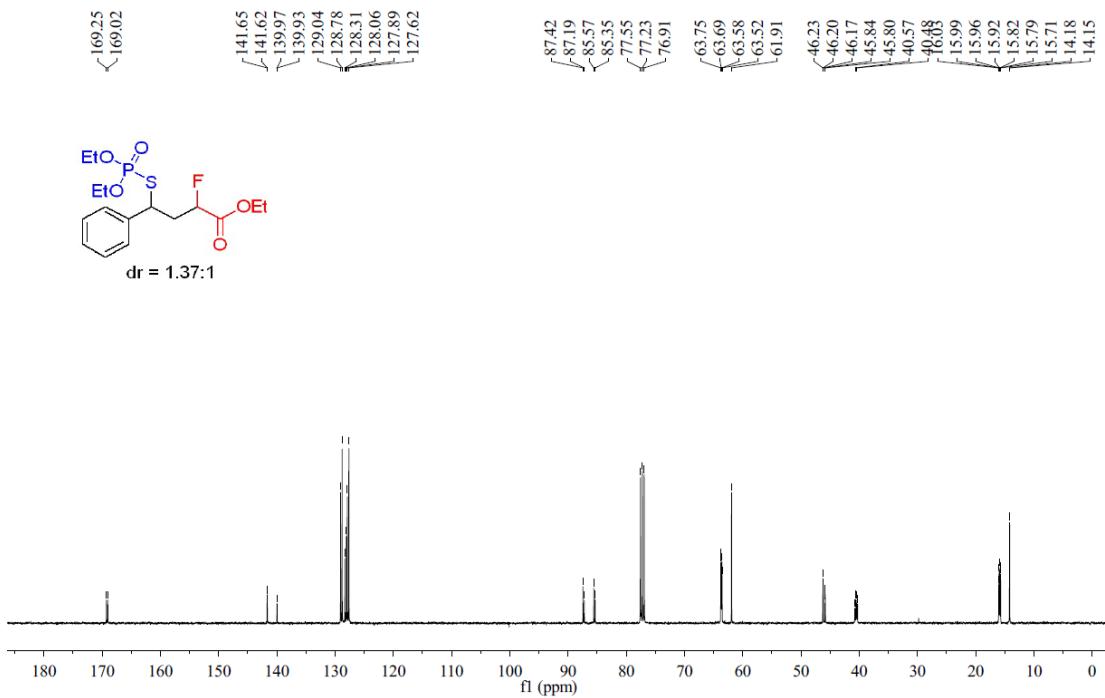
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **6b** in  $\text{CDCl}_3$



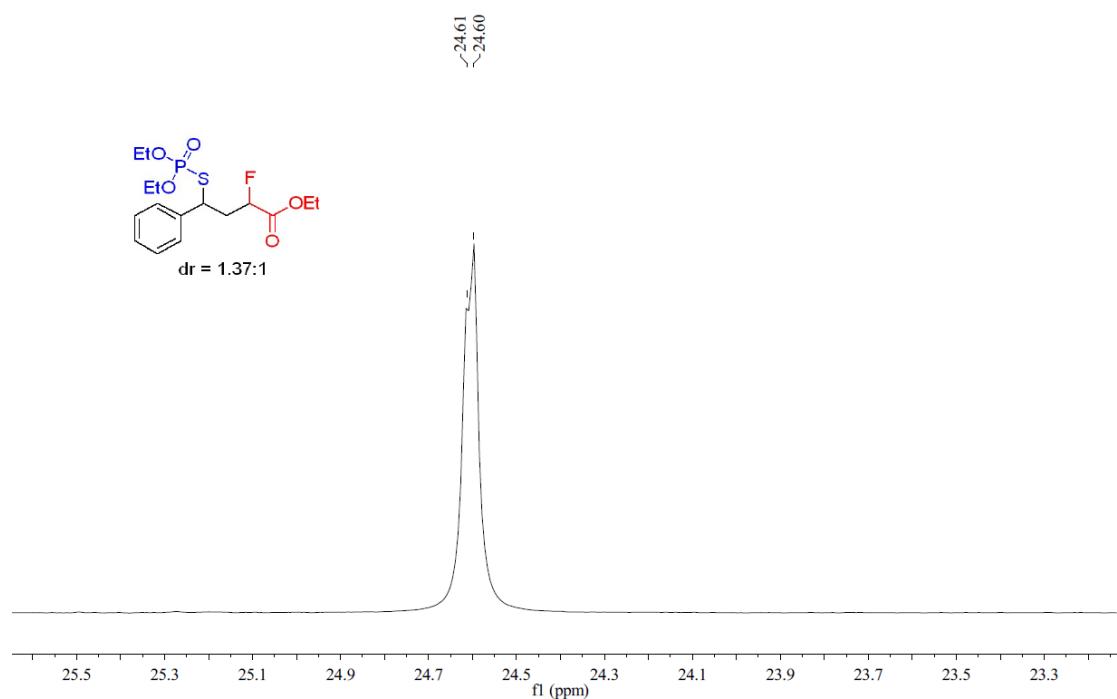
<sup>1</sup>H NMR (400 MHz) Spectrum of **6c** in CDCl<sub>3</sub>



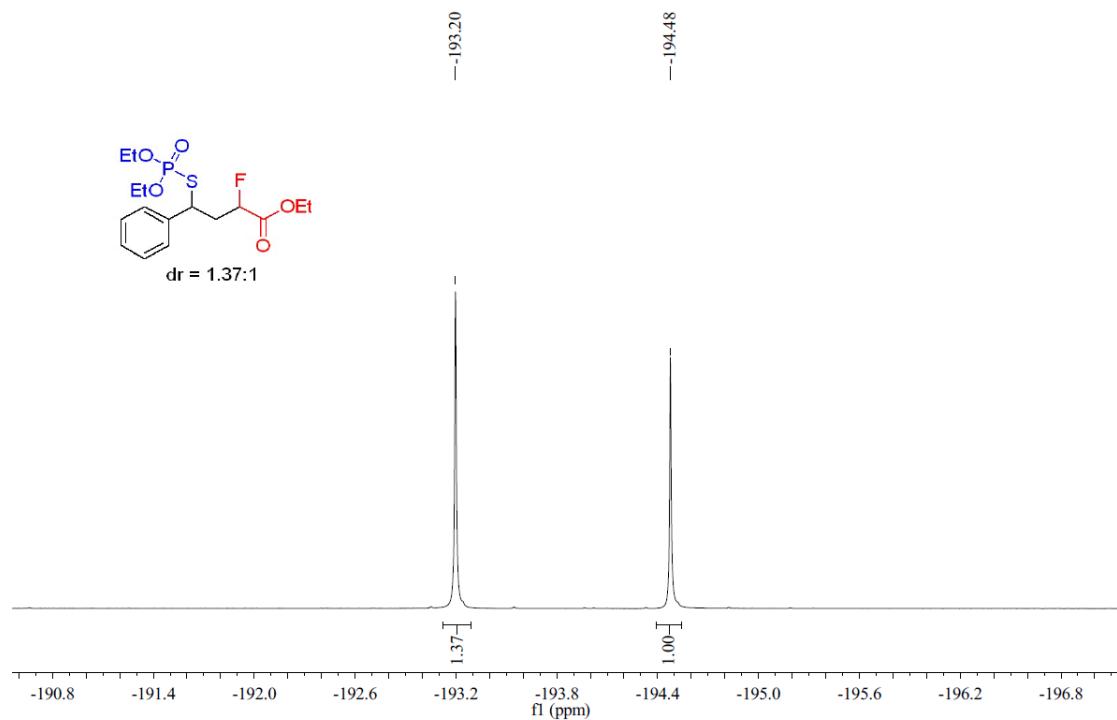
<sup>13</sup>C NMR (151 MHz) Spectrum of **6c** in CDCl<sub>3</sub>



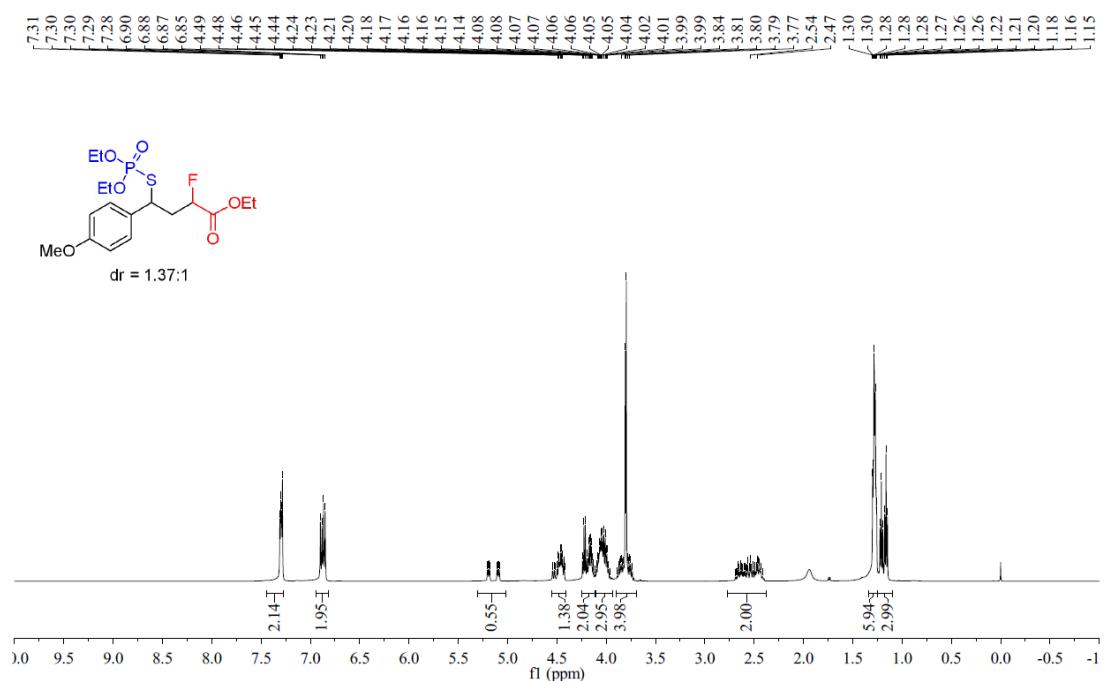
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **6c** in  $\text{CDCl}_3$



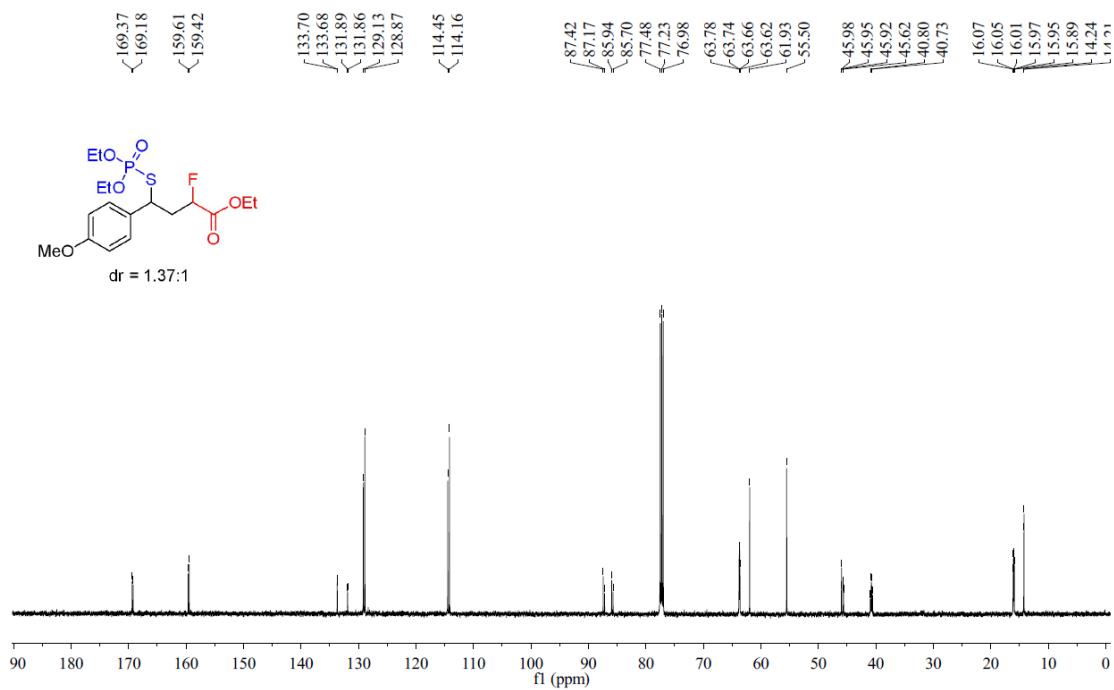
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **6c** in  $\text{CDCl}_3$



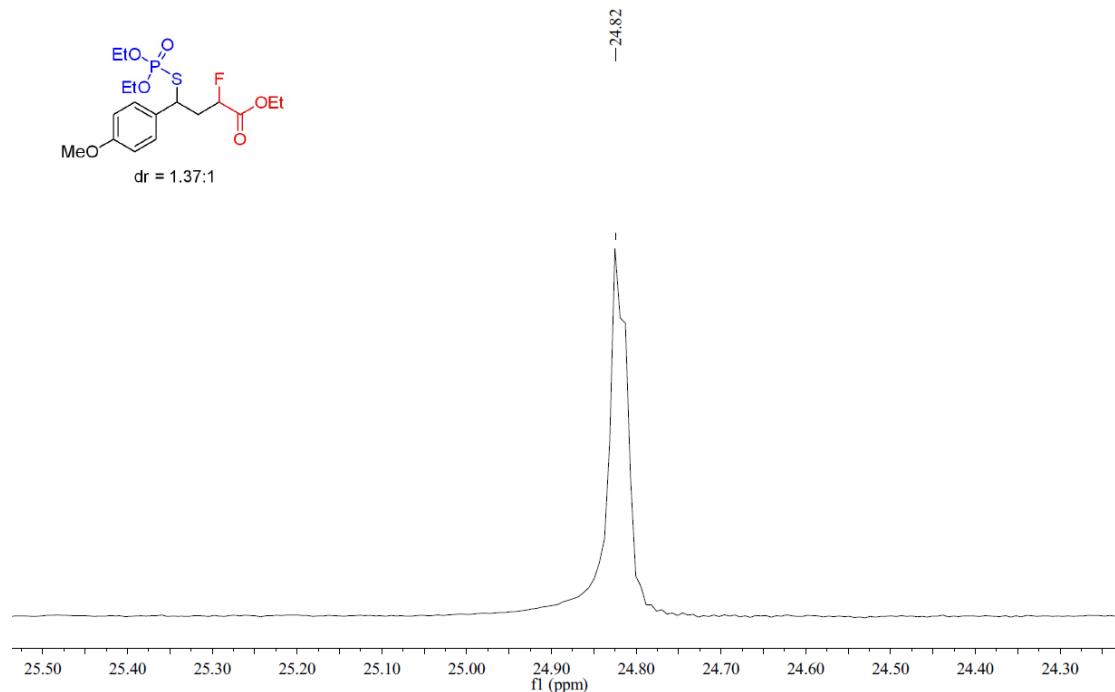
<sup>1</sup>H NMR (400 MHz) Spectrum of **6d** in CDCl<sub>3</sub>



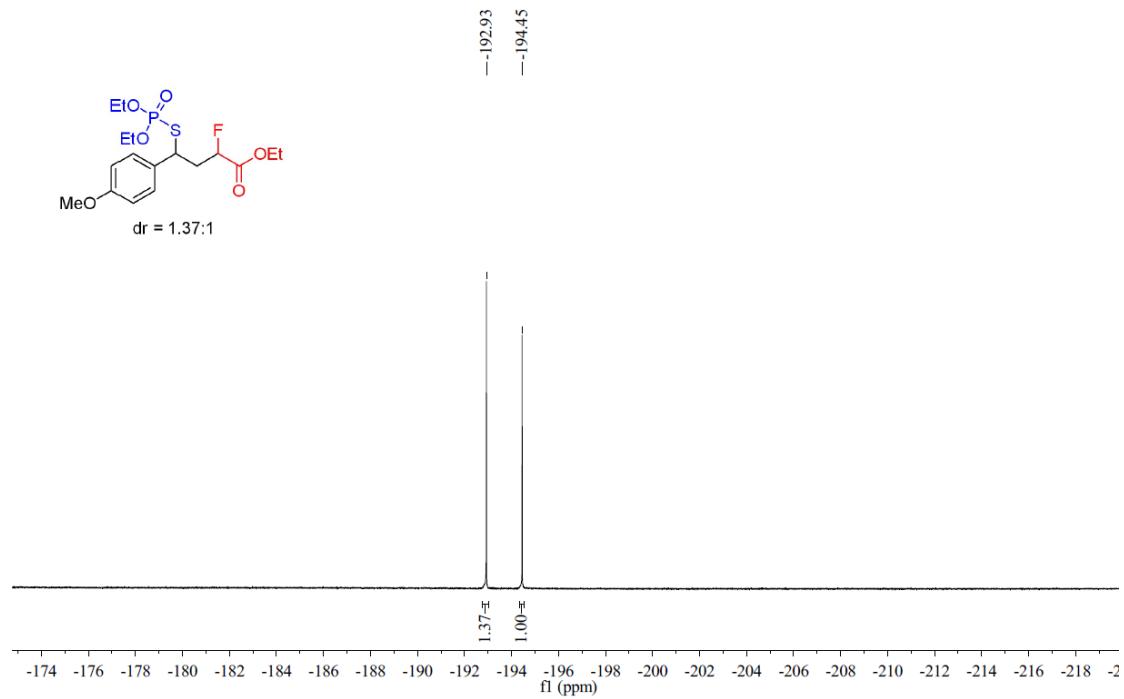
<sup>13</sup>C NMR (151 MHz) Spectrum of **6d** in CDCl<sub>3</sub>



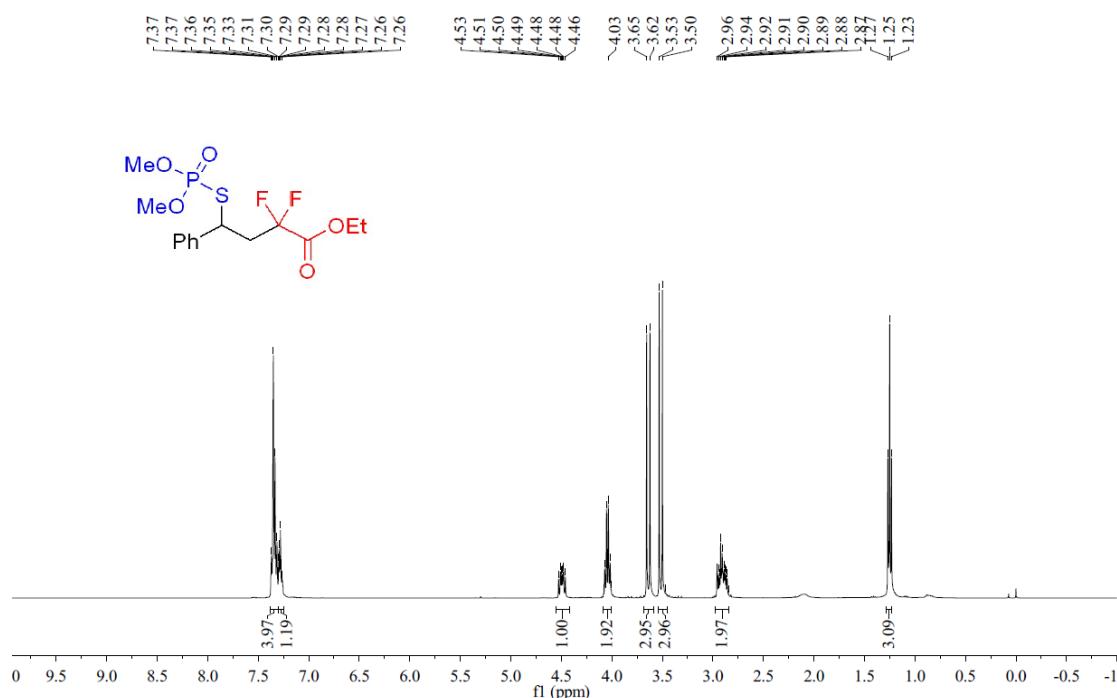
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **6d** in  $\text{CDCl}_3$



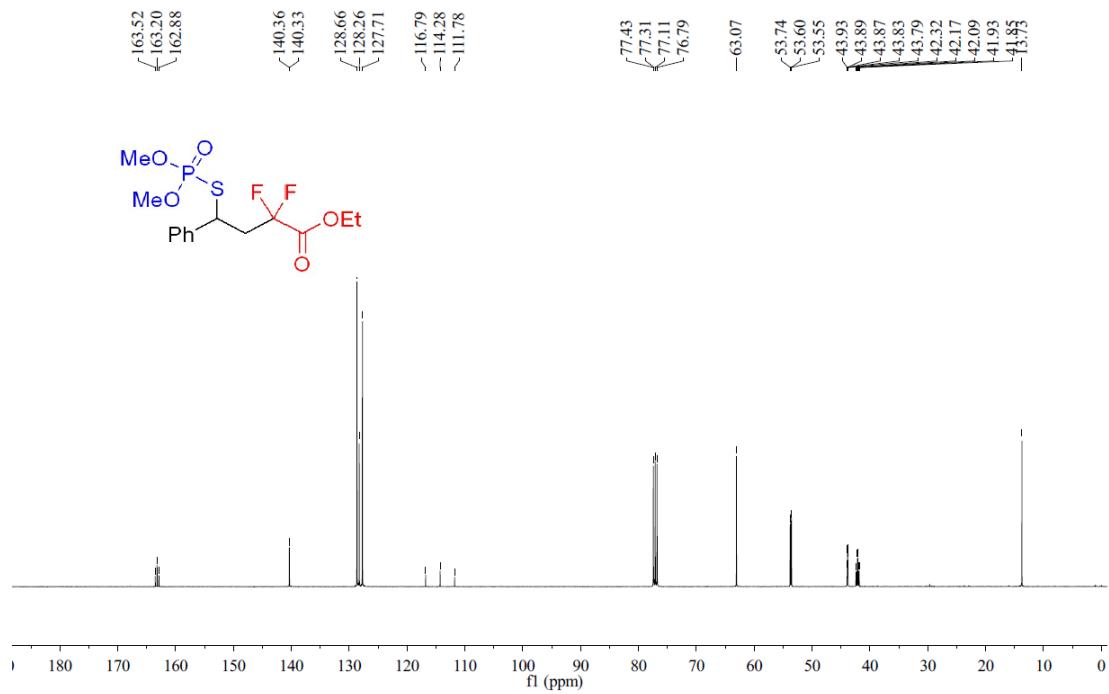
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **6d** in  $\text{CDCl}_3$



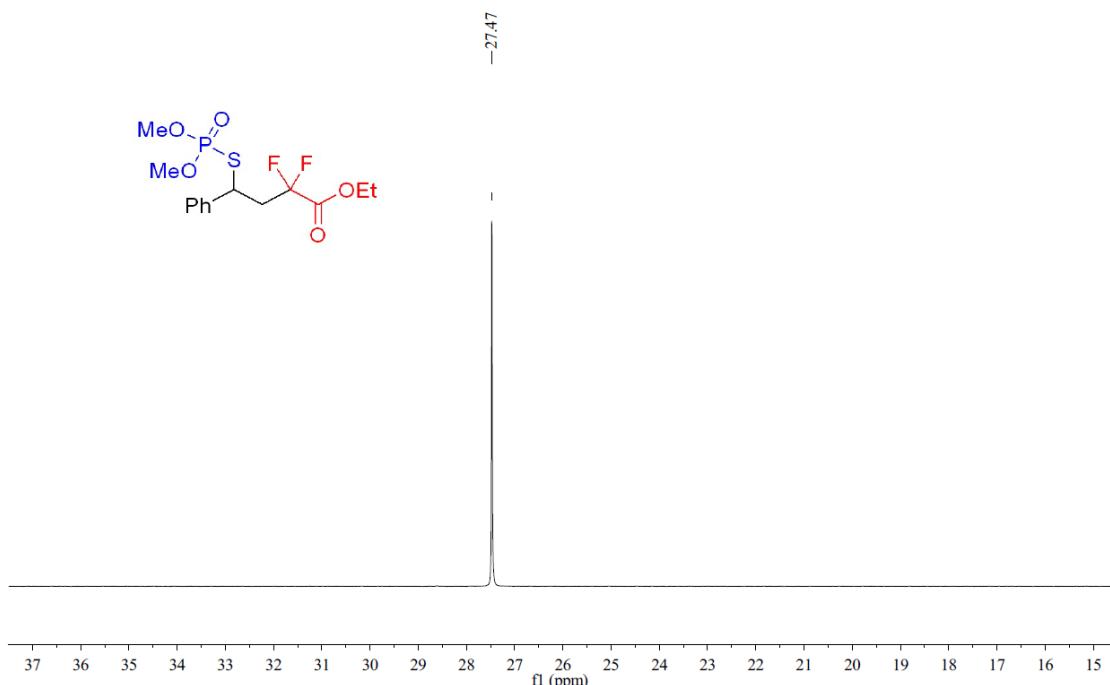
<sup>1</sup>H NMR (400 MHz) Spectrum of **6e** in CDCl<sub>3</sub>



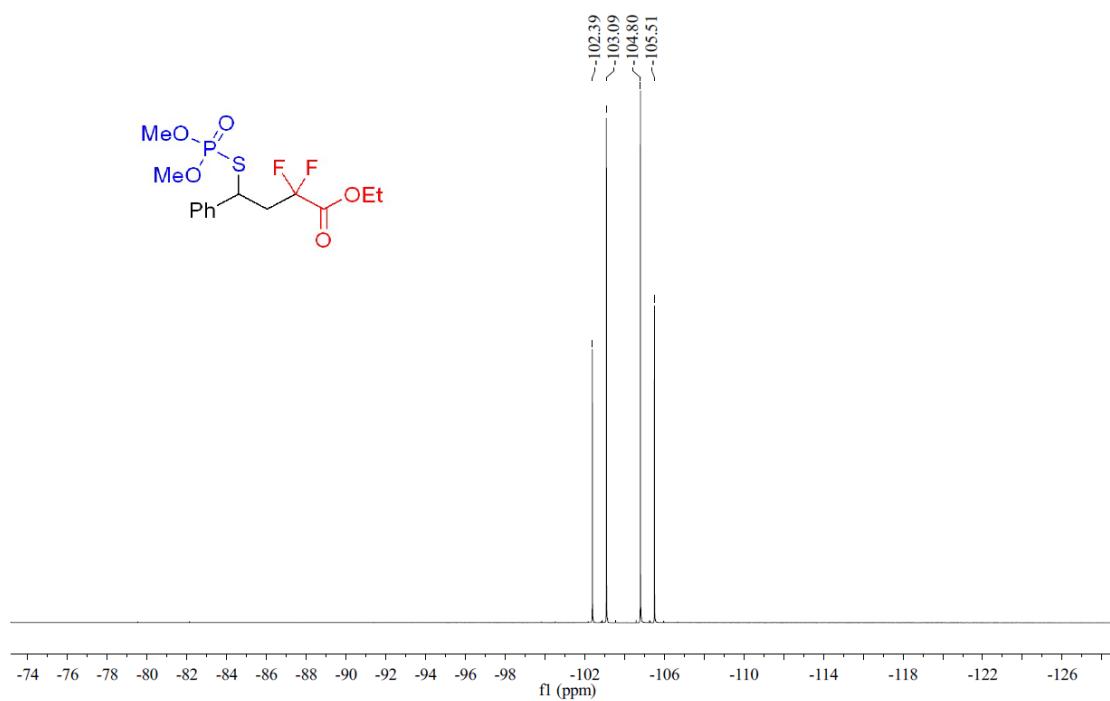
<sup>13</sup>C NMR (151 MHz) Spectrum of **6e** in CDCl<sub>3</sub>



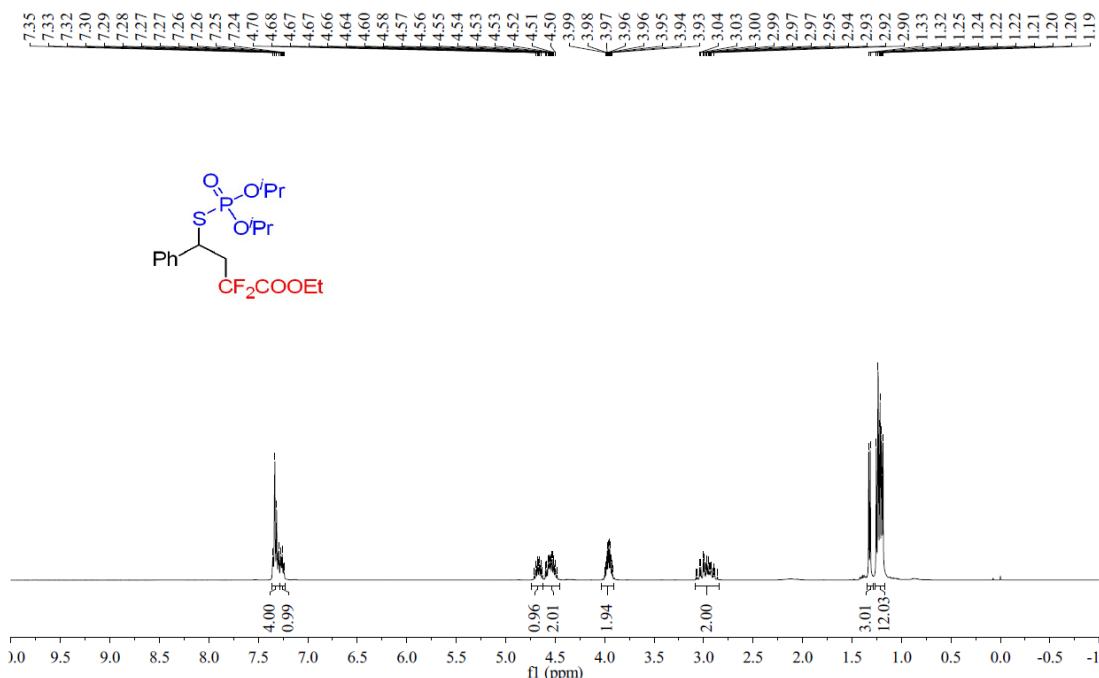
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **6e** in  $\text{CDCl}_3$



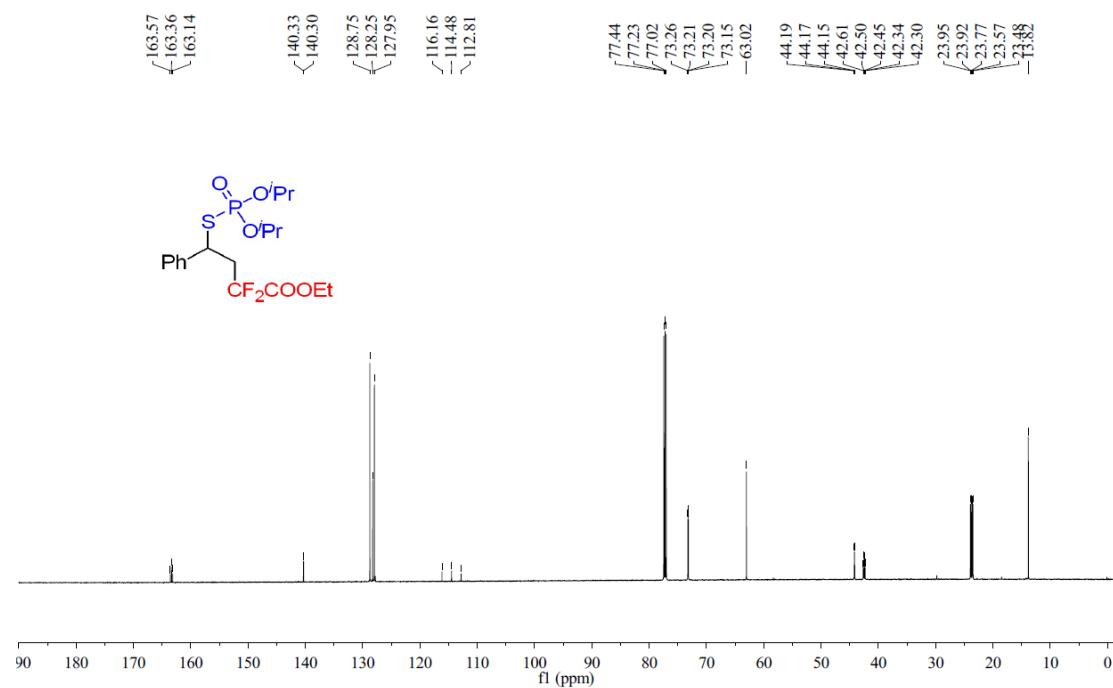
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **6e** in  $\text{CDCl}_3$



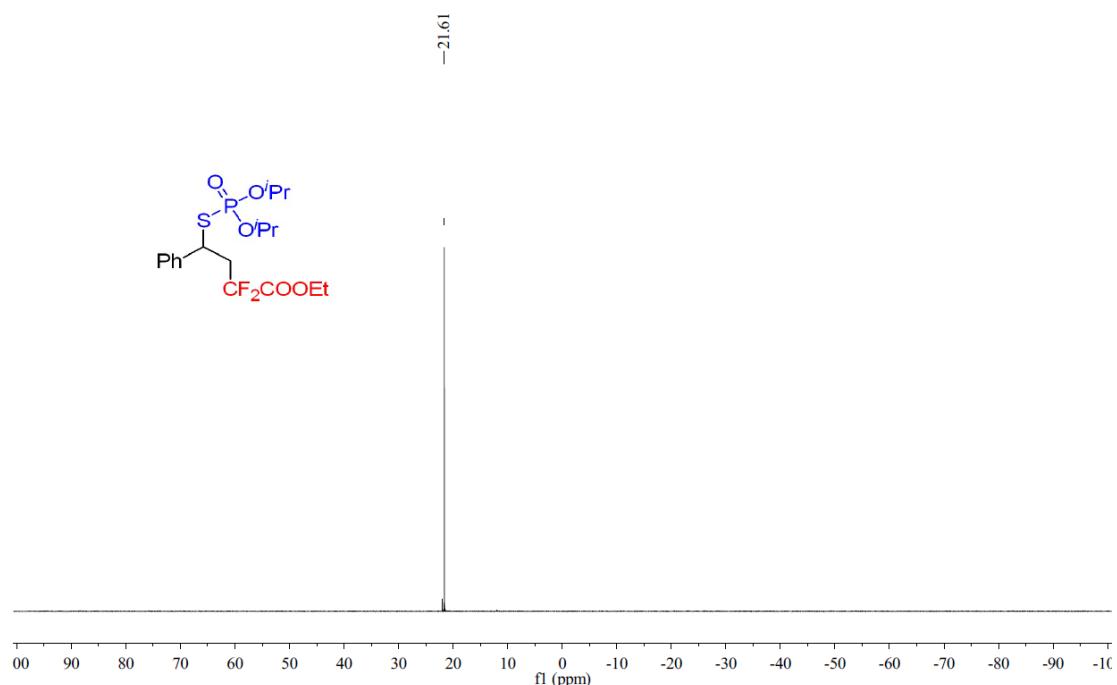
<sup>1</sup>H NMR (400 MHz) Spectrum of **6f** in CDCl<sub>3</sub>



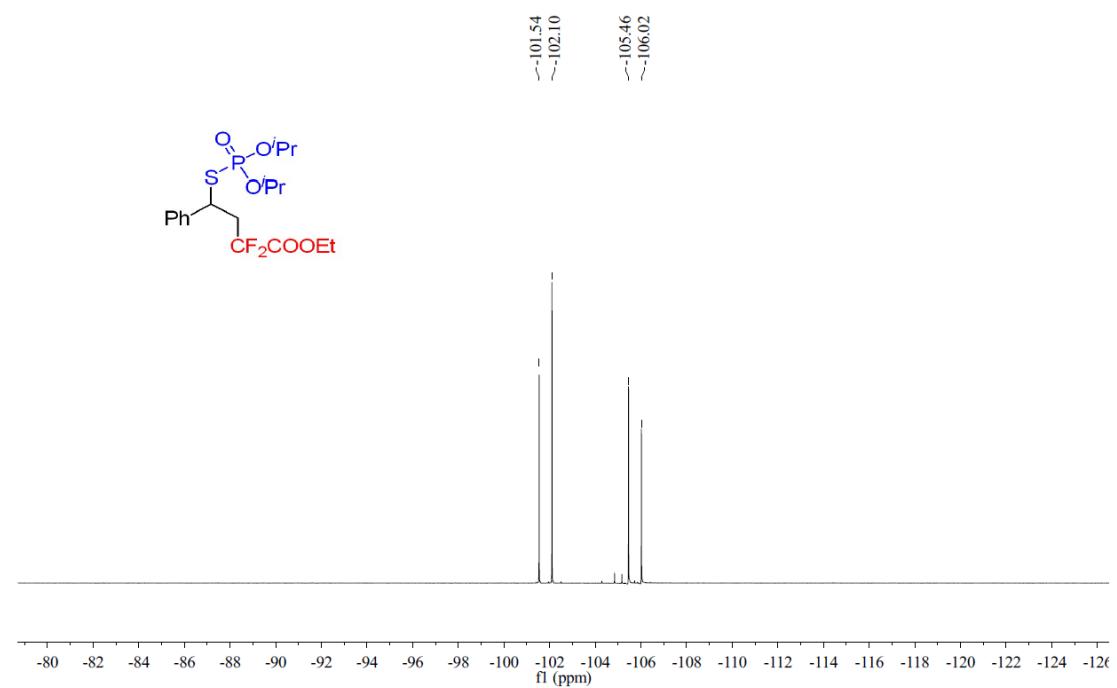
<sup>13</sup>C NMR (151 MHz) Spectrum of **6f** in CDCl<sub>3</sub>



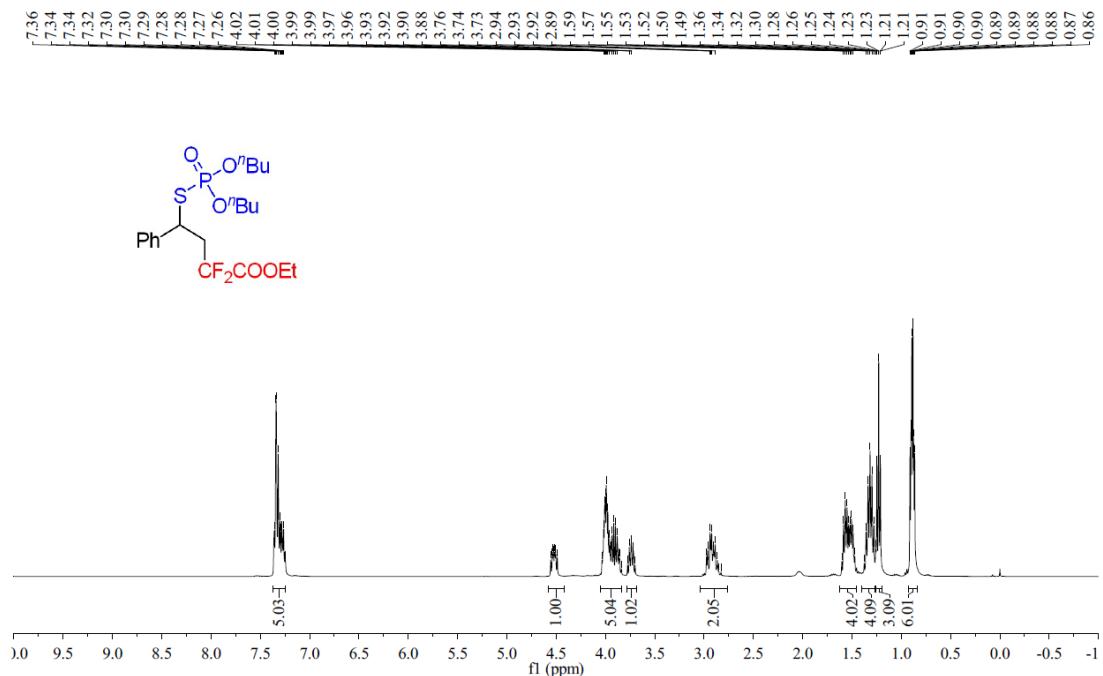
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **6f** in  $\text{CDCl}_3$



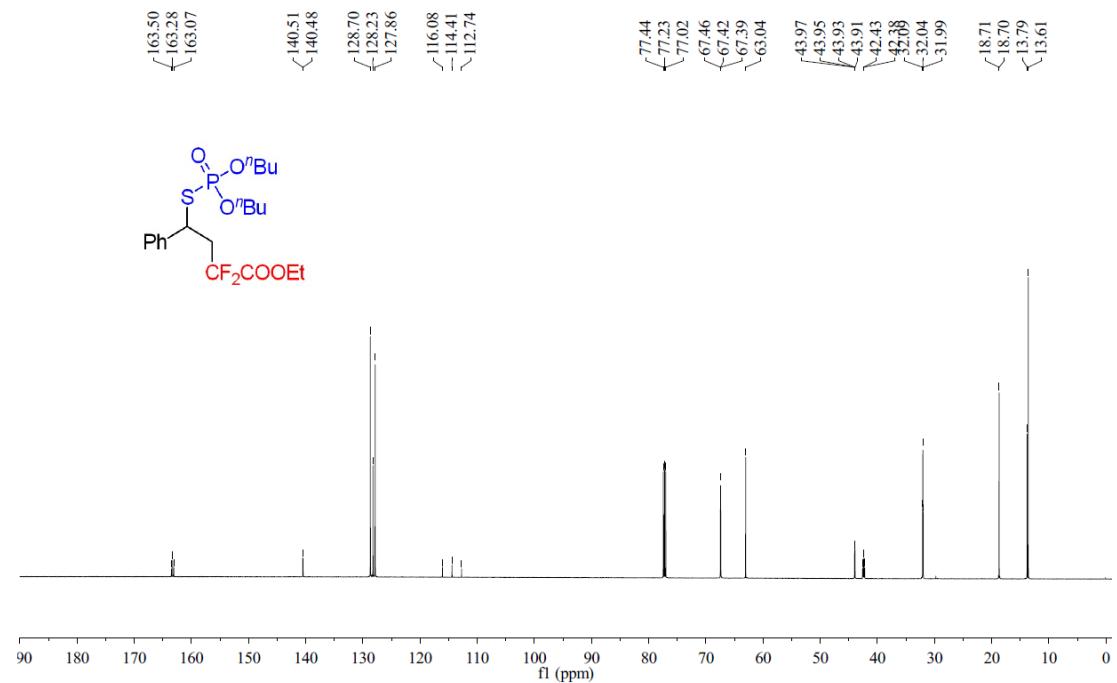
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **6f** in  $\text{CDCl}_3$



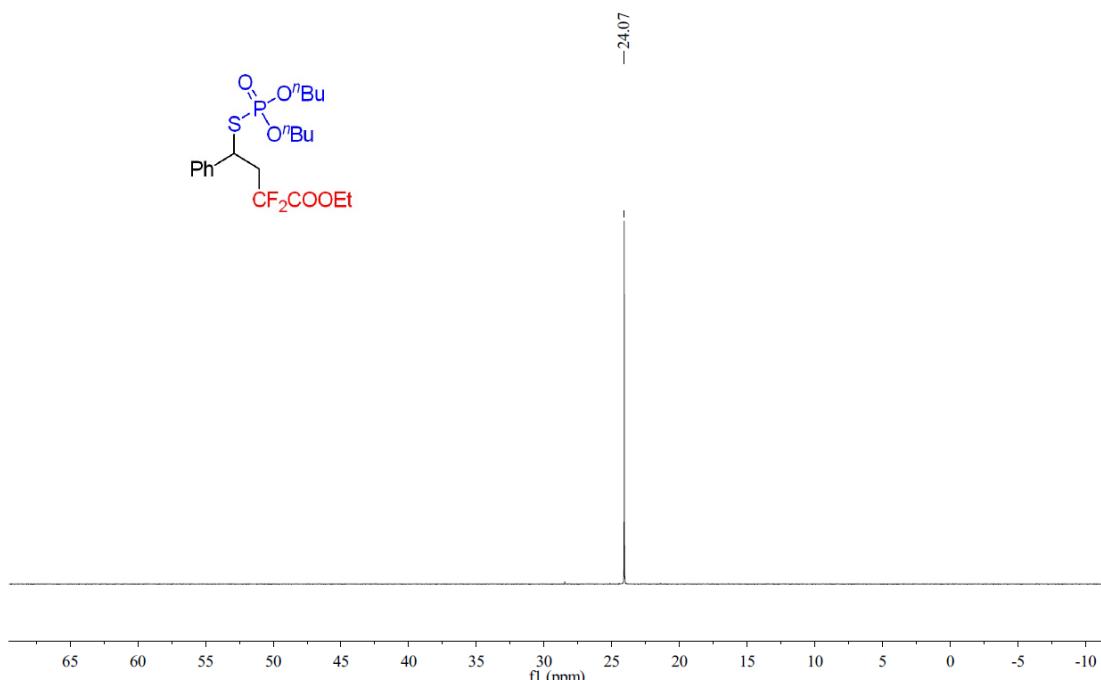
<sup>1</sup>H NMR (400 MHz) Spectrum of **6g** in CDCl<sub>3</sub>



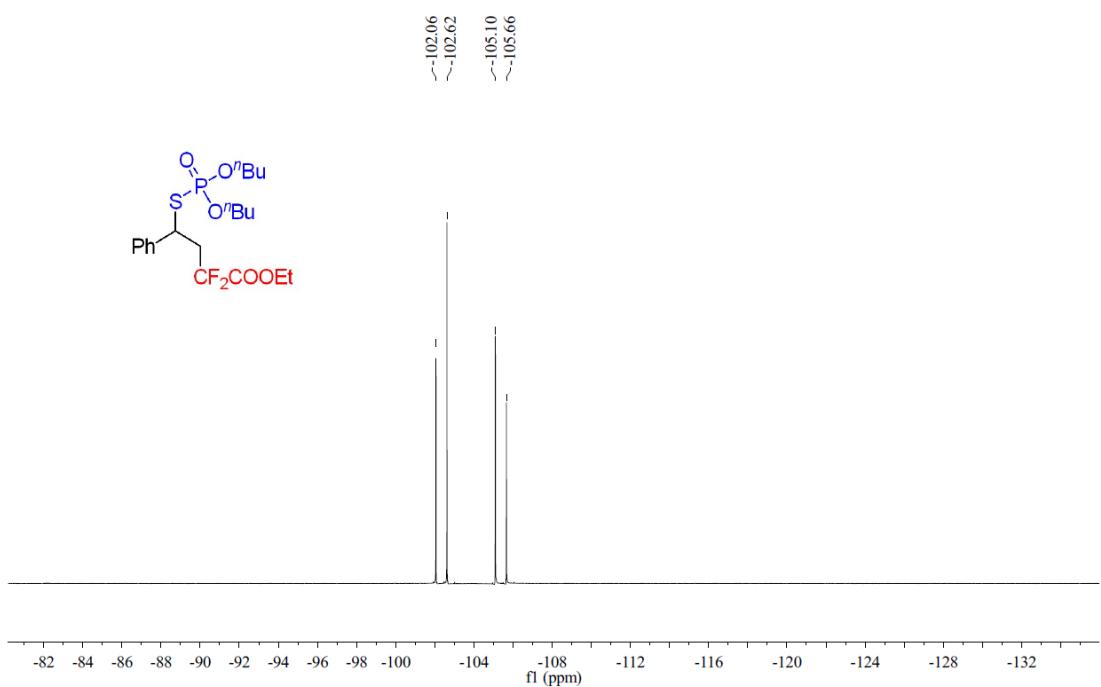
<sup>13</sup>C NMR (151 MHz) Spectrum of **6g** in CDCl<sub>3</sub>



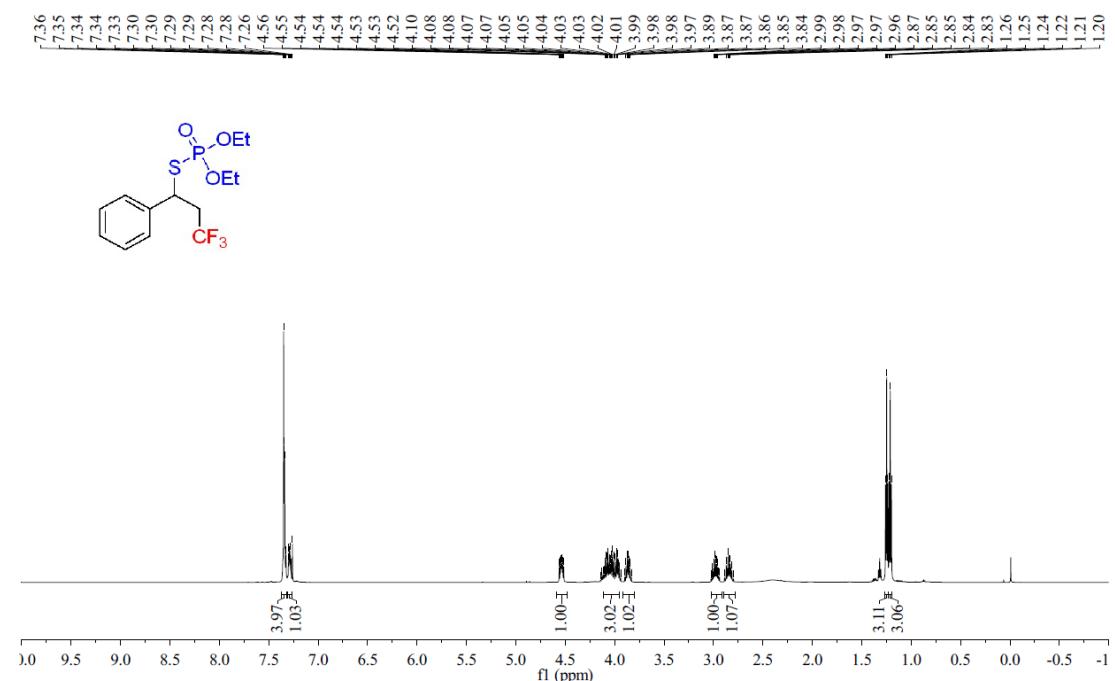
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **6g** in  $\text{CDCl}_3$



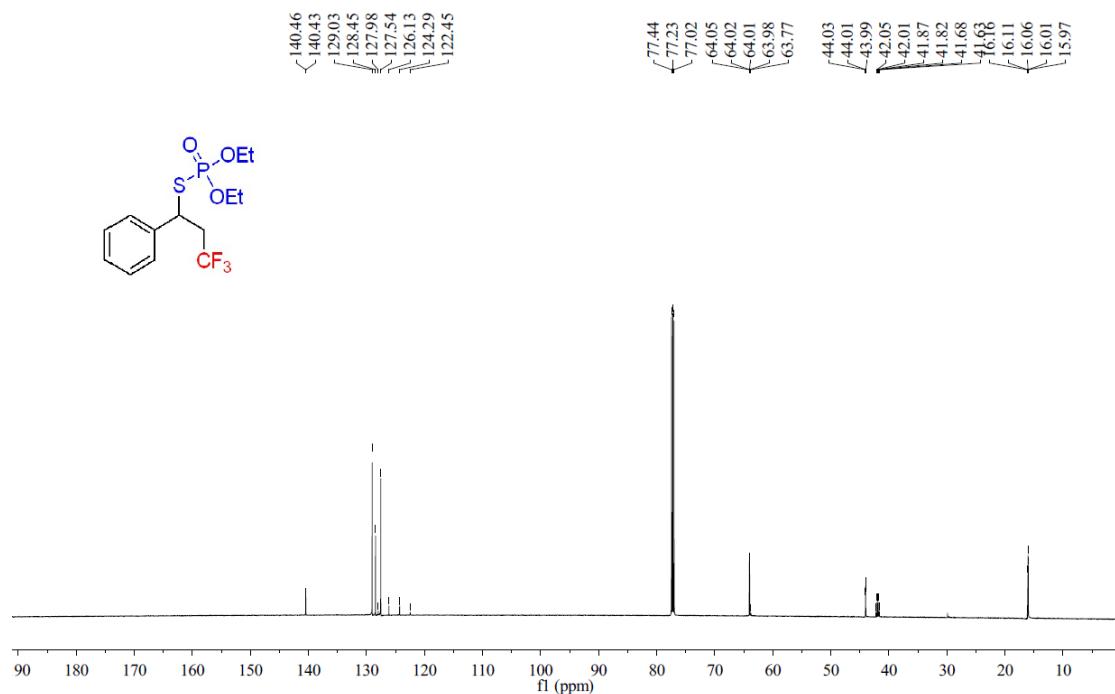
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **6g** in  $\text{CDCl}_3$



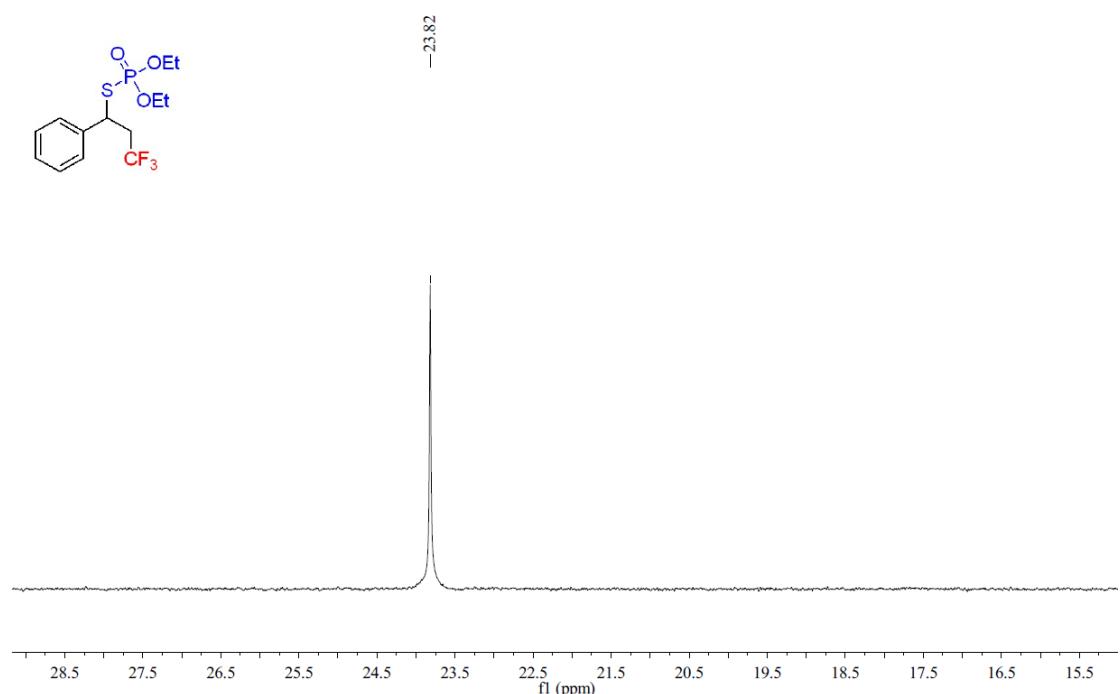
<sup>1</sup>H NMR (400 MHz) Spectrum of **7a** in CDCl<sub>3</sub>



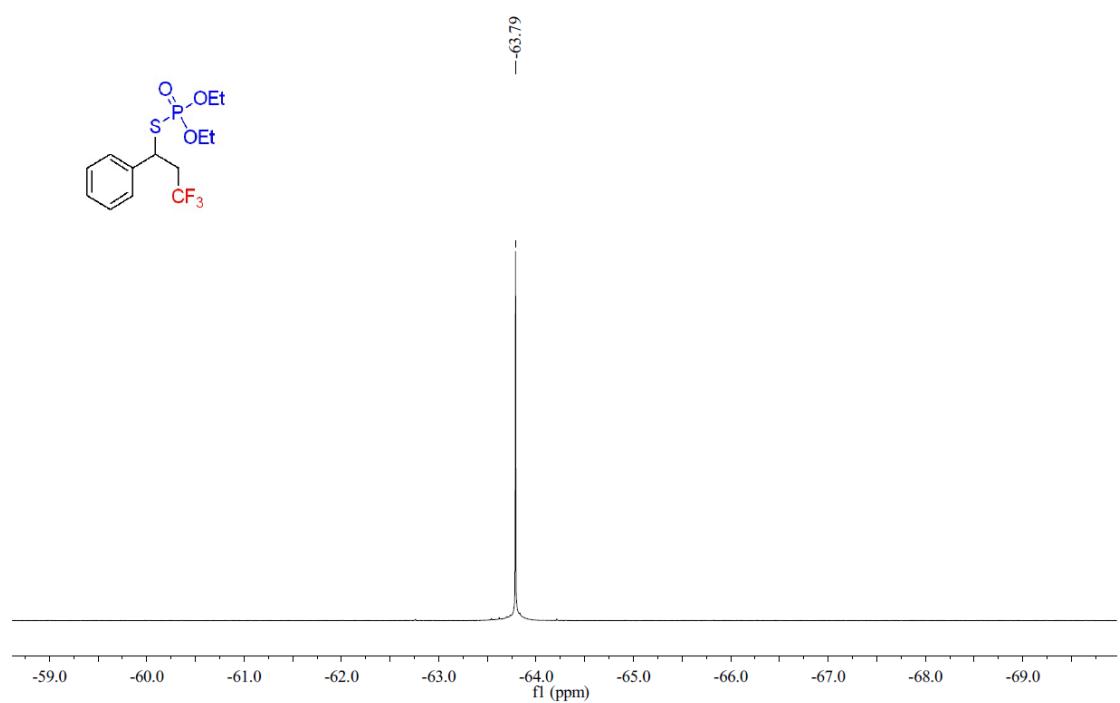
<sup>13</sup>C NMR (151 MHz) Spectrum of **7a** in CDCl<sub>3</sub>



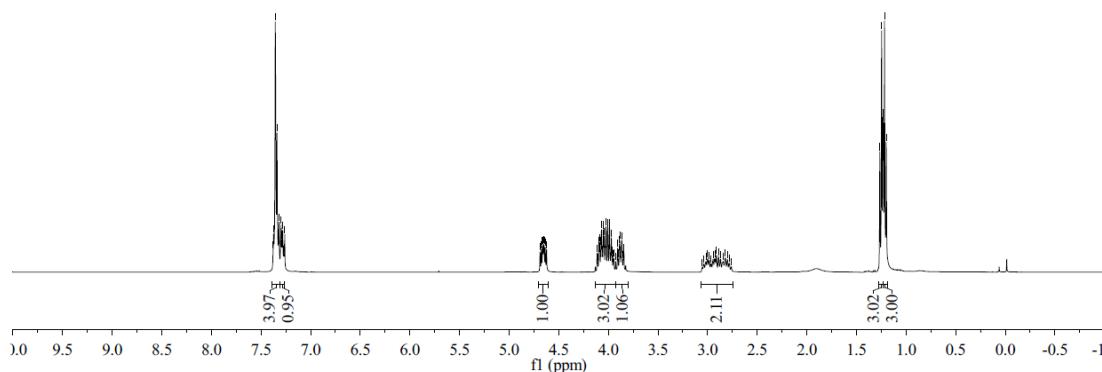
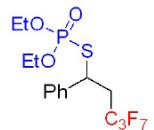
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **7a** in  $\text{CDCl}_3$



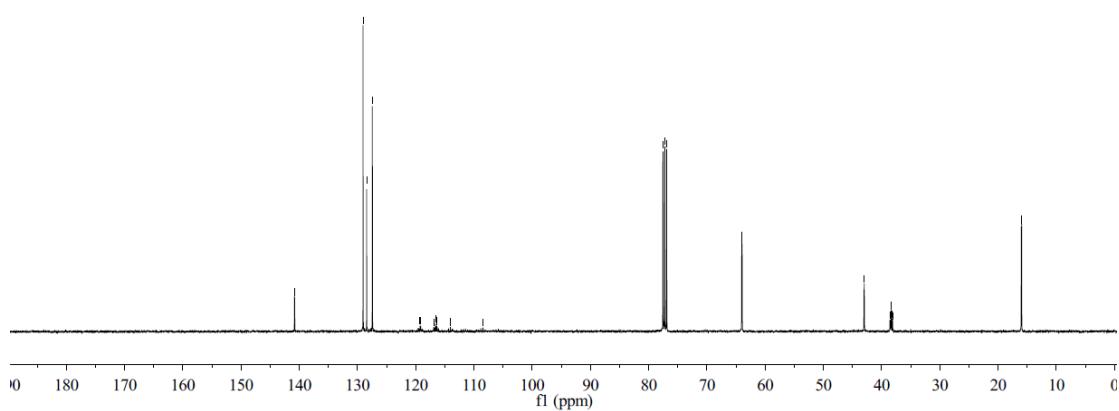
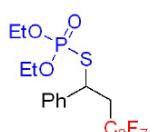
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **7a** in  $\text{CDCl}_3$



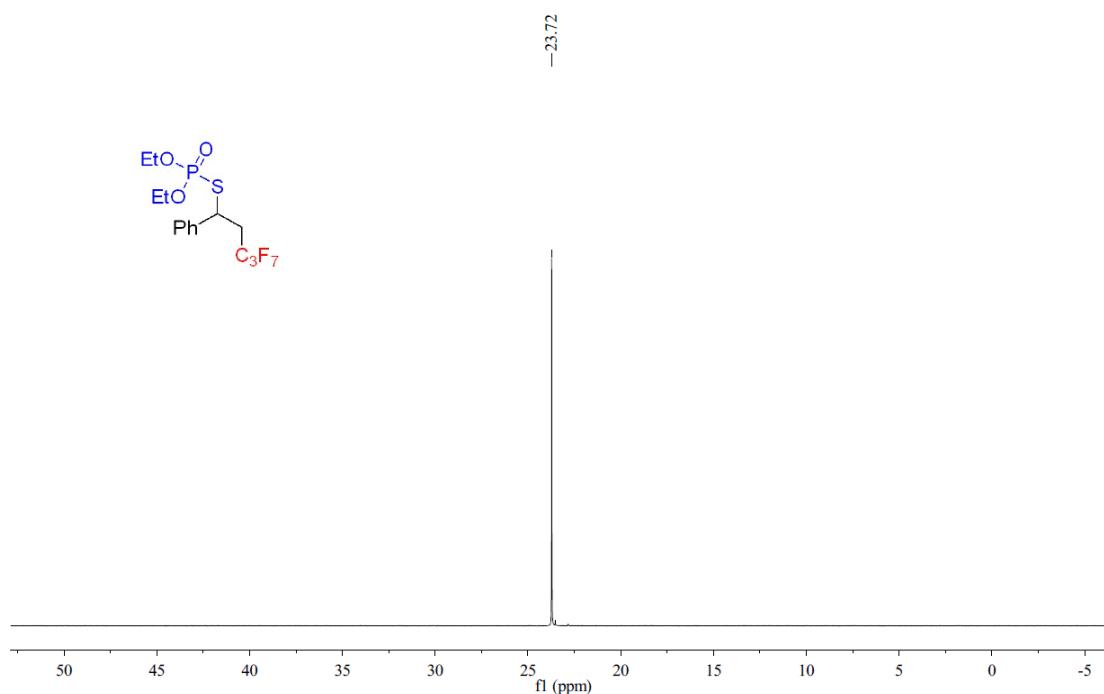
<sup>1</sup>H NMR (400 MHz) Spectrum of **7b** in CDCl<sub>3</sub>



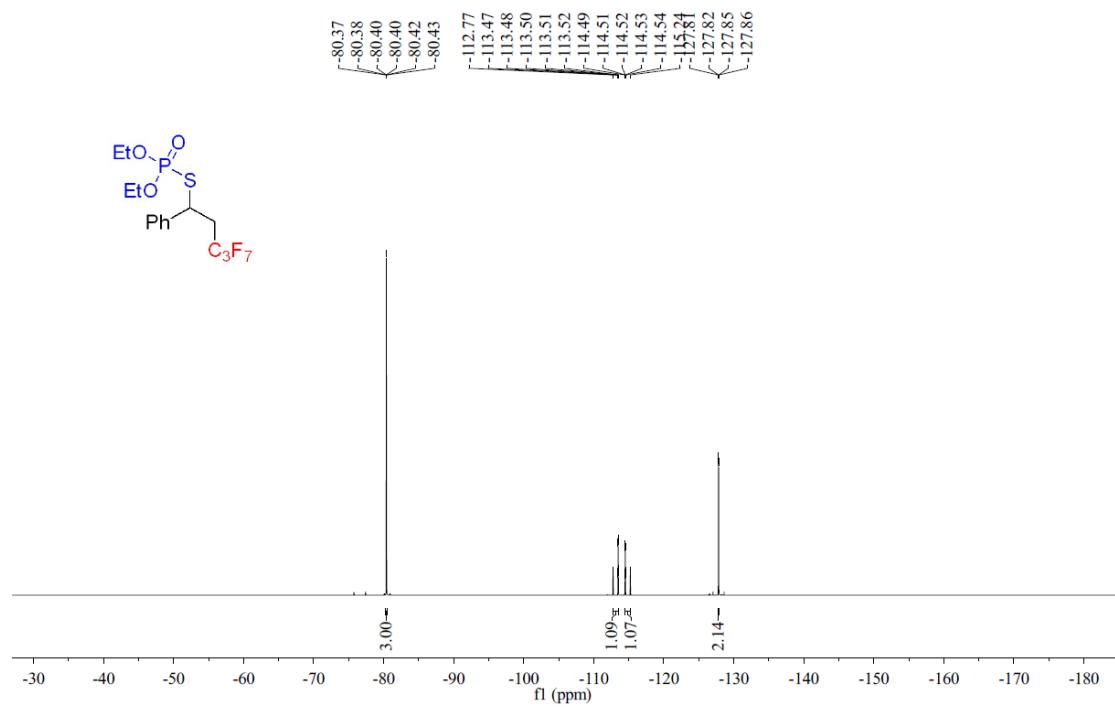
<sup>13</sup>C NMR (151 MHz) Spectrum of **7b** in CDCl<sub>3</sub>



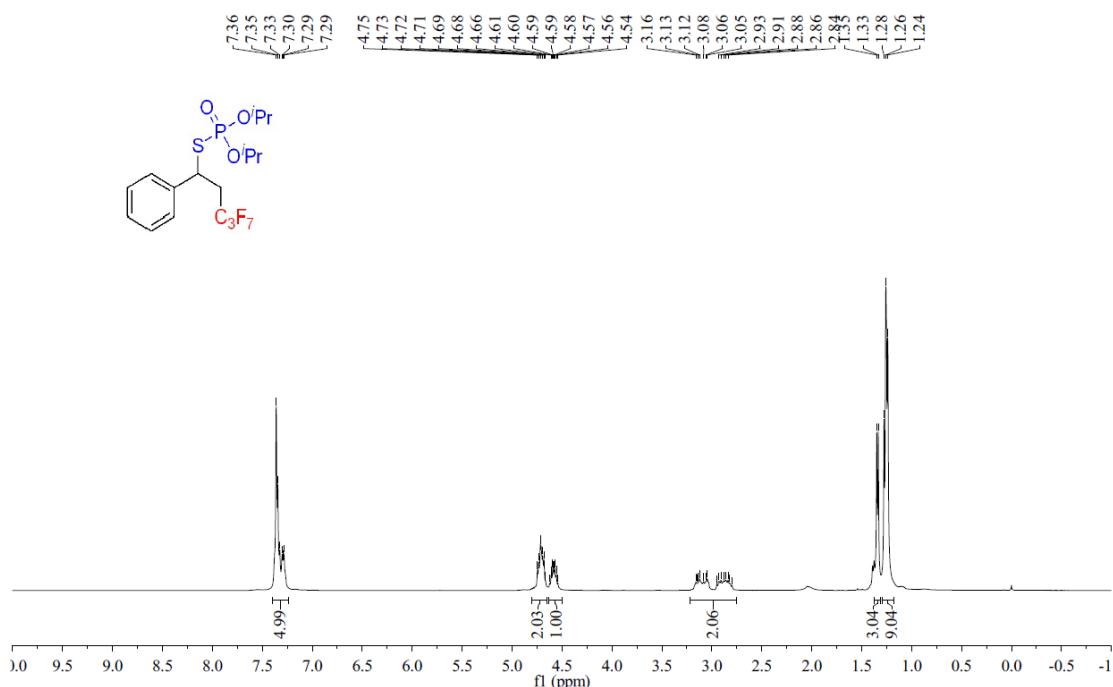
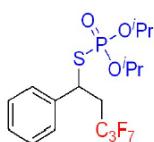
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **7b** in  $\text{CDCl}_3$



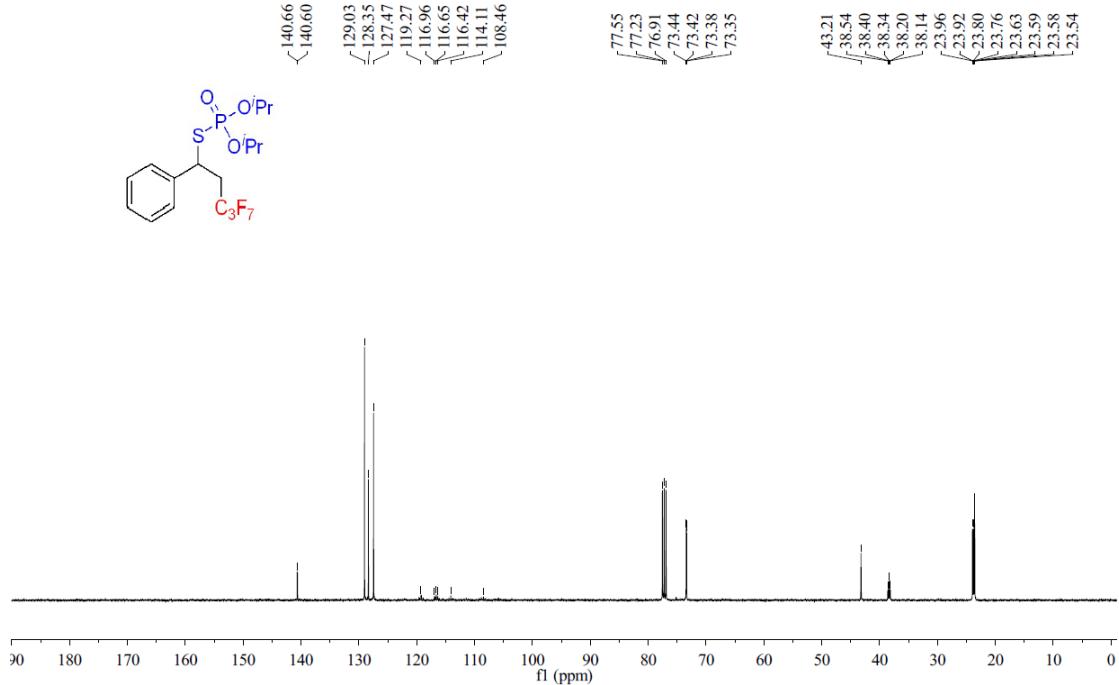
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **7b** in  $\text{CDCl}_3$



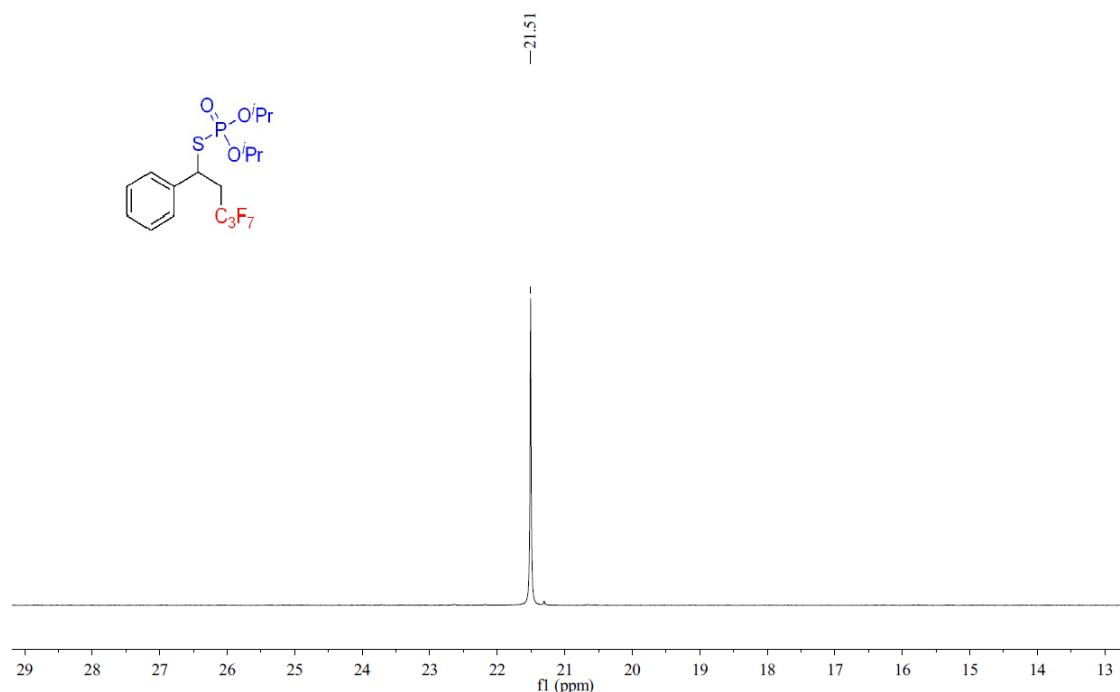
<sup>1</sup>H NMR (400 MHz) Spectrum of **7c** in CDCl<sub>3</sub>



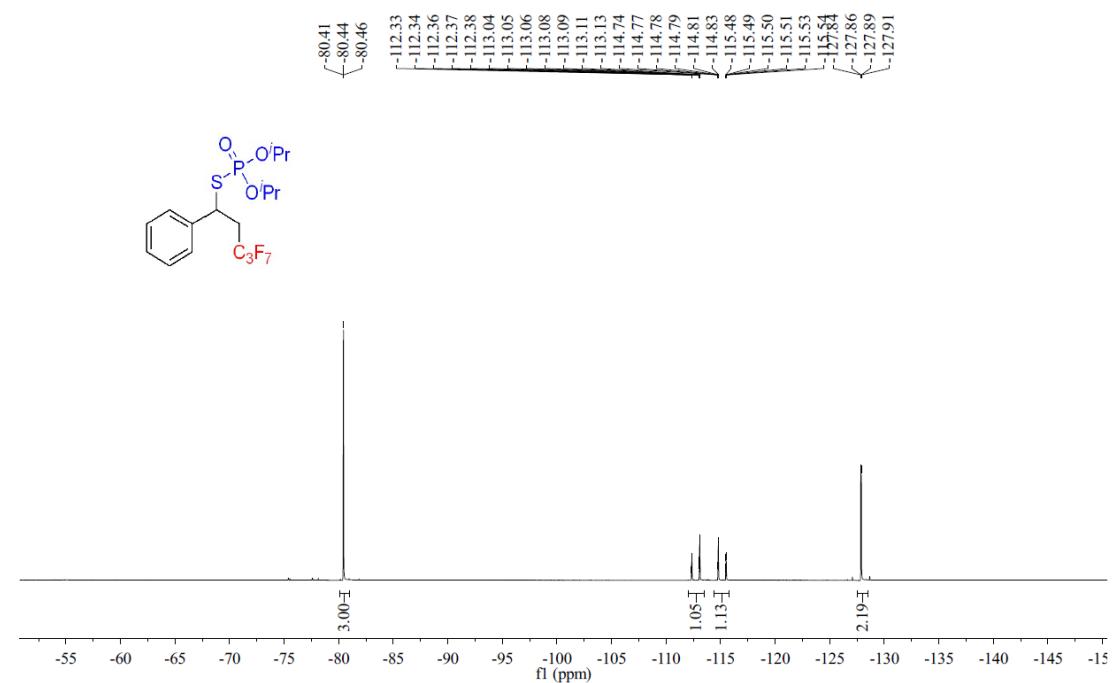
<sup>13</sup>C NMR (151 MHz) Spectrum of **7c** in CDCl<sub>3</sub>



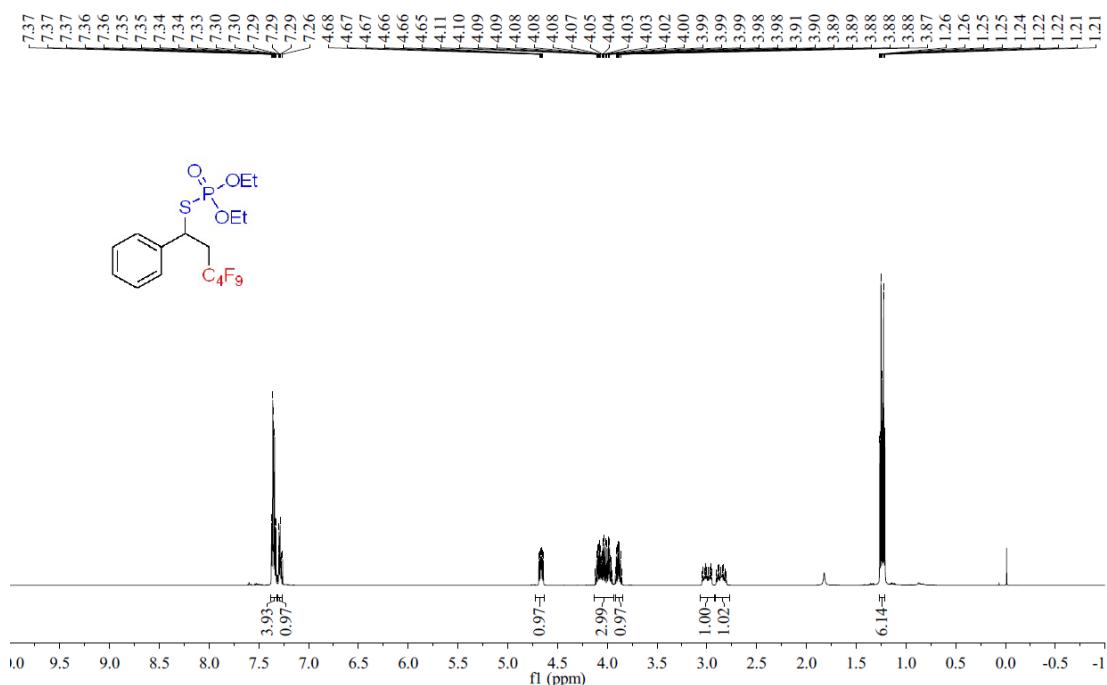
<sup>31</sup>P NMR (243 MHz) Spectrum of **7c** in CDCl<sub>3</sub>



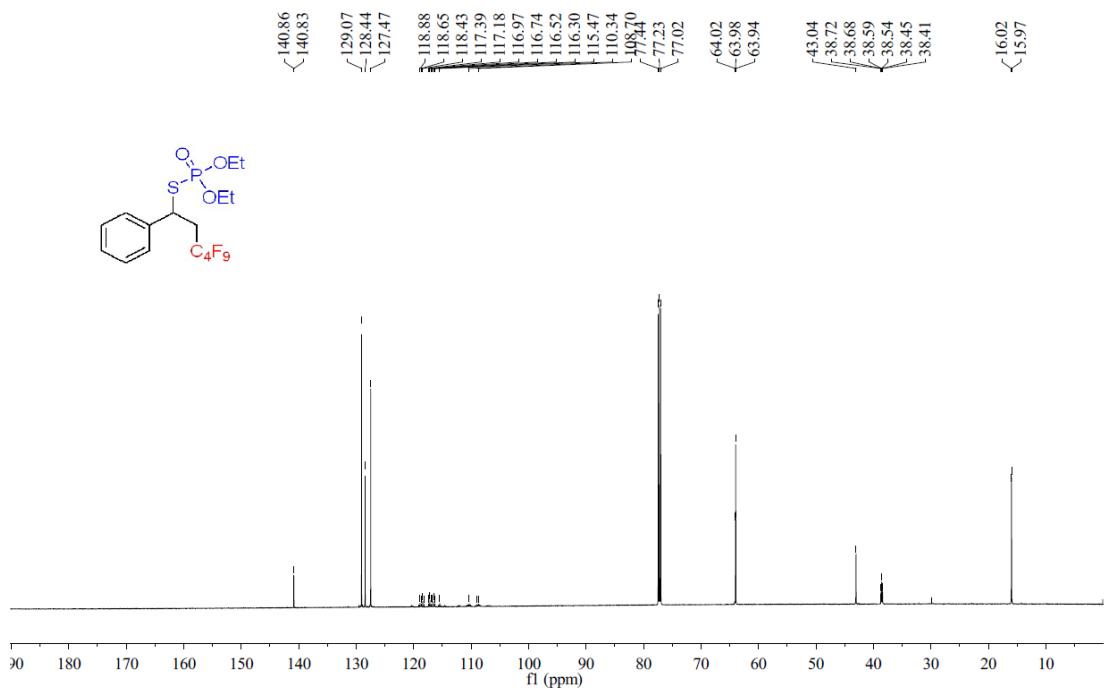
<sup>19</sup>F NMR (471 MHz) Spectrum of **7c** in CDCl<sub>3</sub>



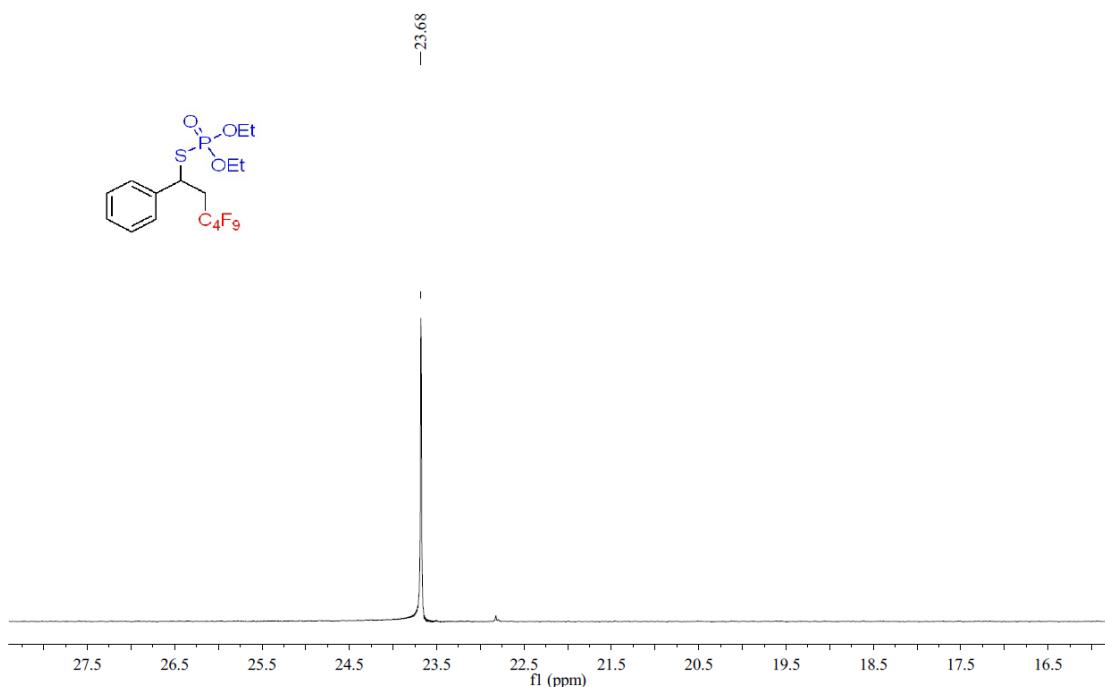
<sup>1</sup>H NMR (400 MHz) Spectrum of **7d** in CDCl<sub>3</sub>



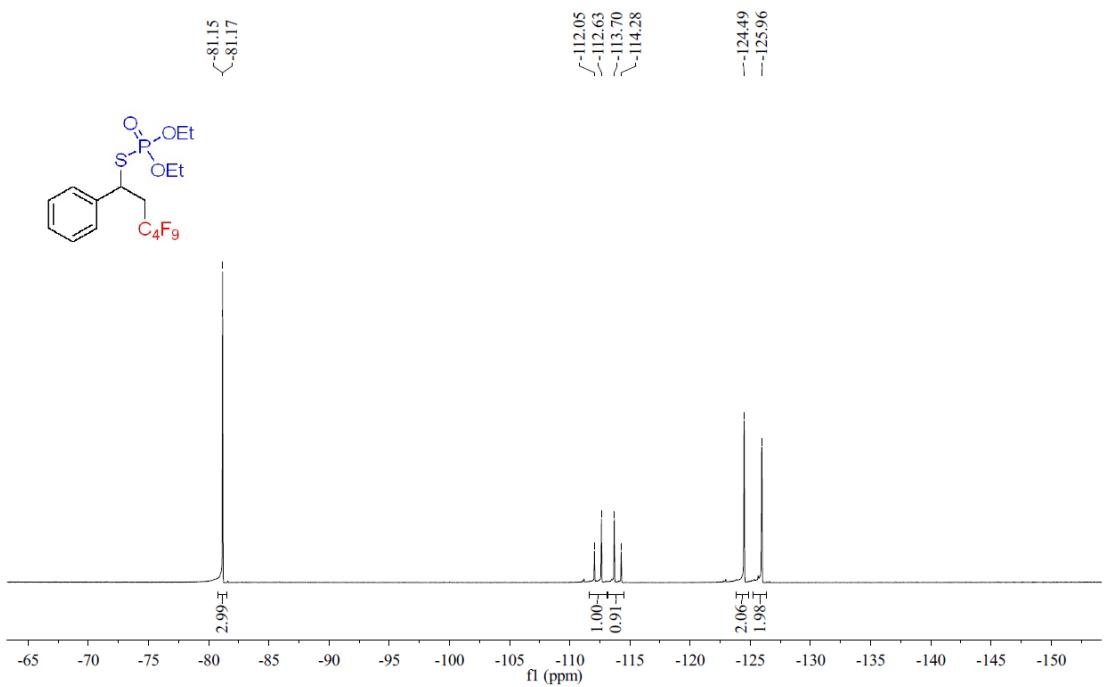
<sup>13</sup>C NMR (151 MHz) Spectrum of **7d** in CDCl<sub>3</sub>



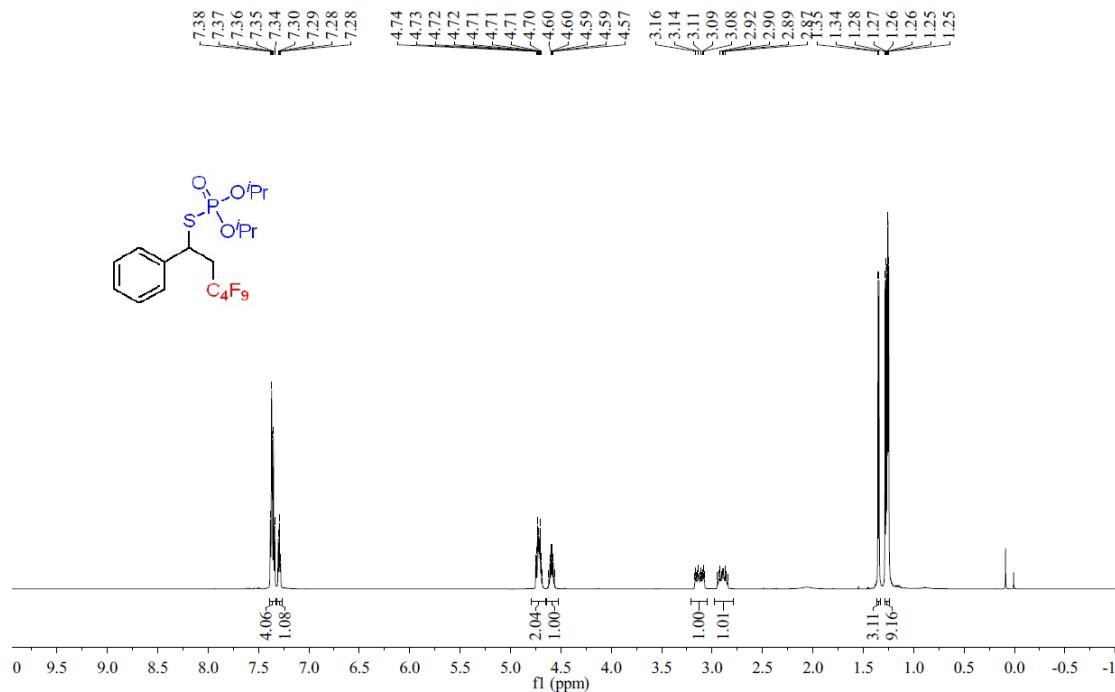
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **7d** in  $\text{CDCl}_3$



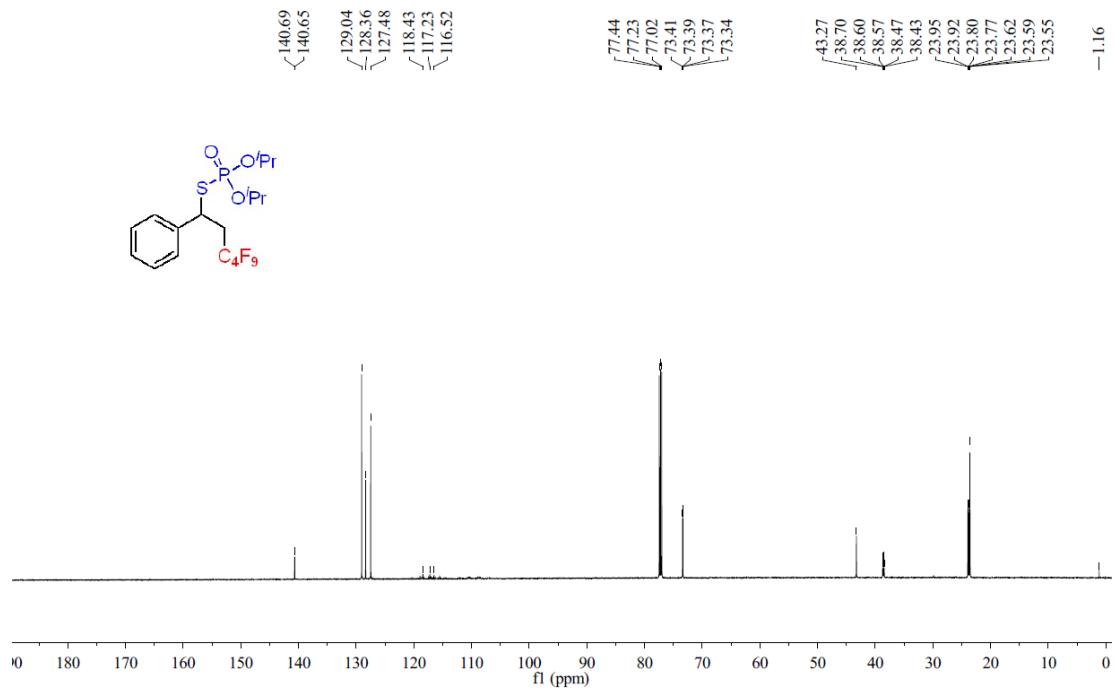
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **7d** in  $\text{CDCl}_3$



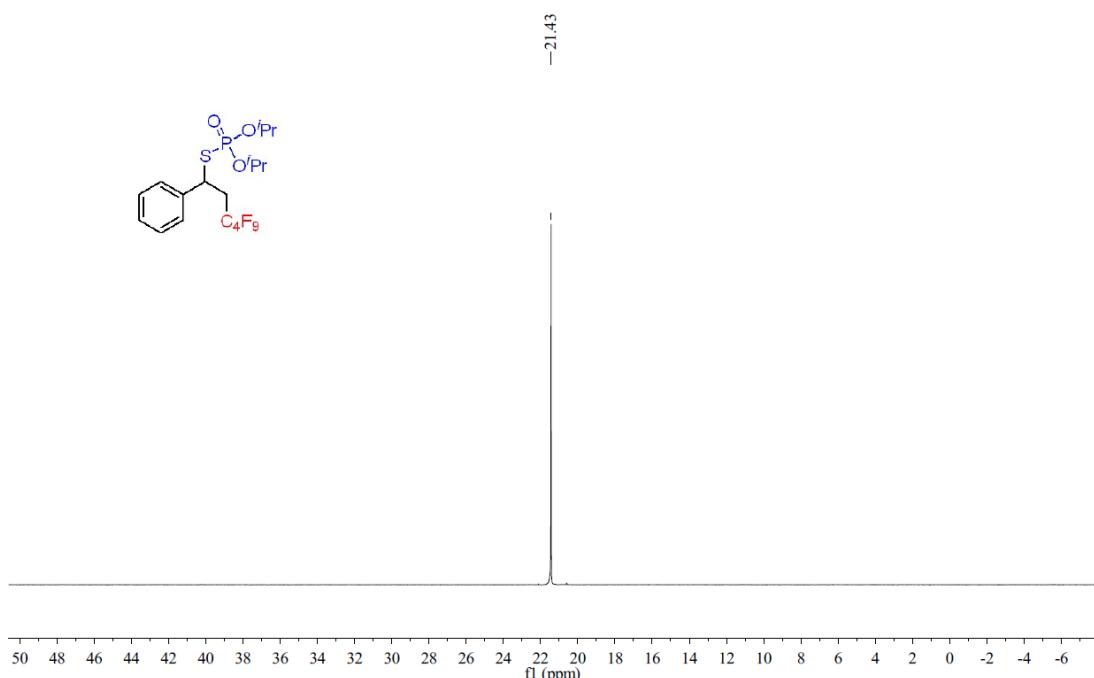
<sup>1</sup>H NMR (400 MHz) Spectrum of **7e** in CDCl<sub>3</sub>



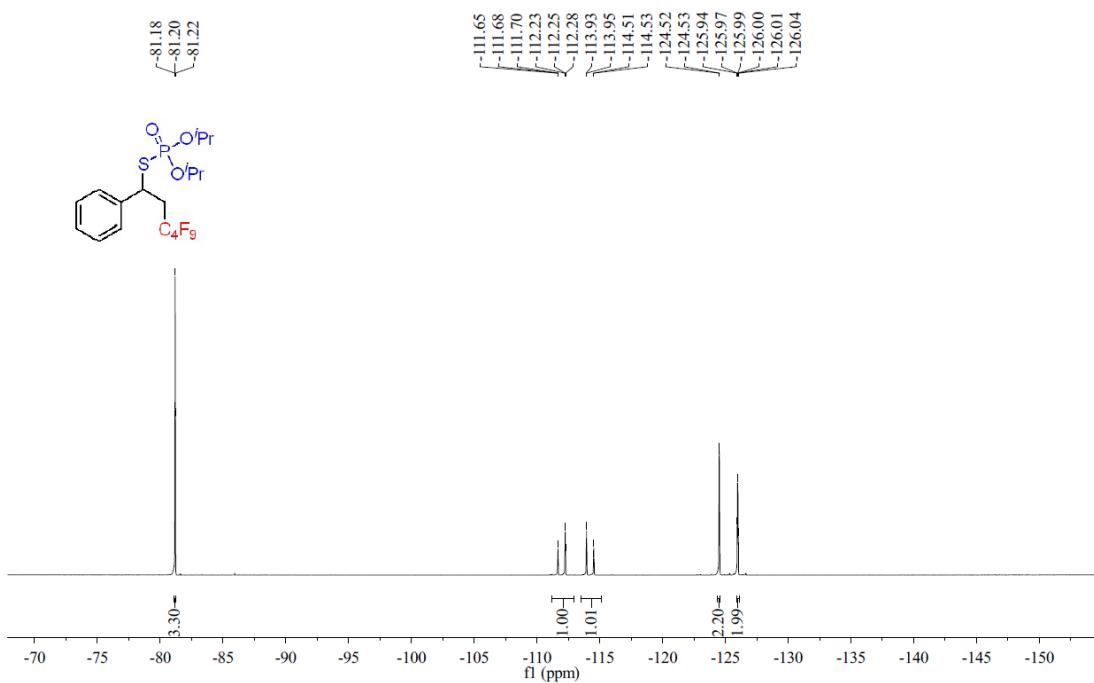
<sup>13</sup>C NMR (151 MHz) Spectrum of **7e** in CDCl<sub>3</sub>



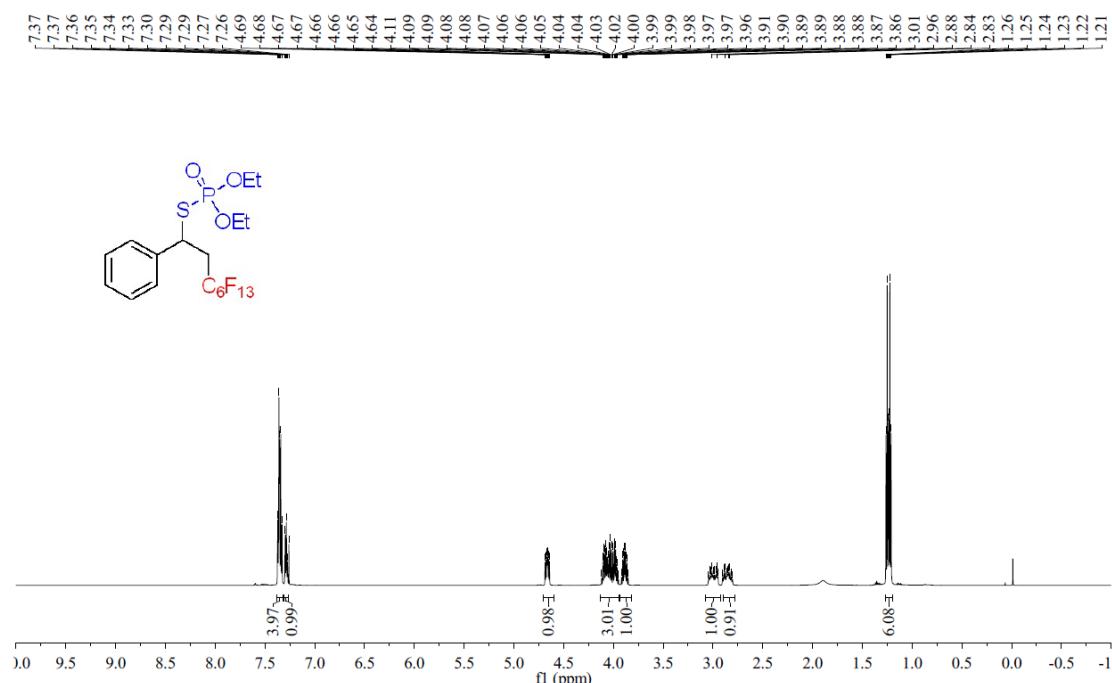
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **7e** in  $\text{CDCl}_3$



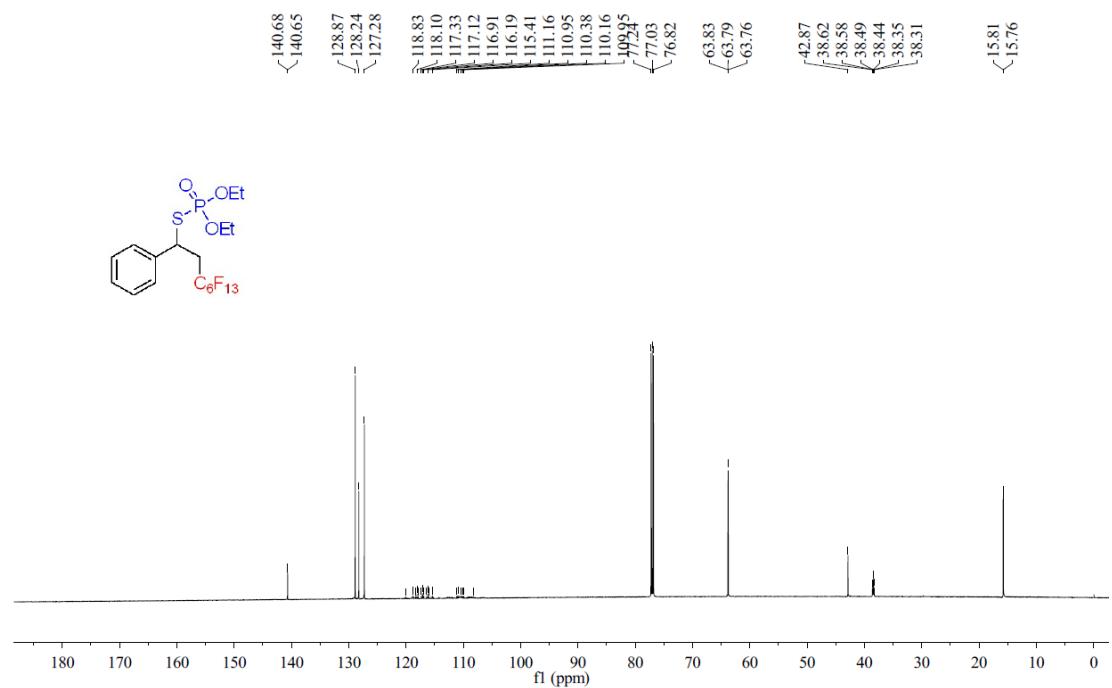
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **7e** in  $\text{CDCl}_3$



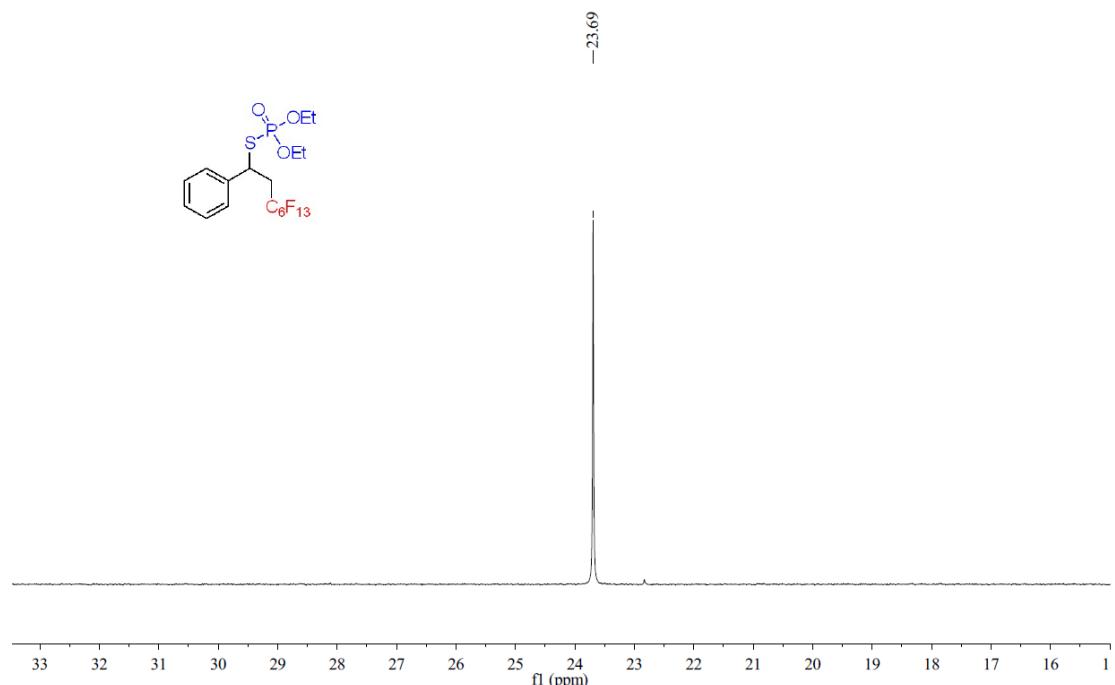
<sup>1</sup>H NMR (400 MHz) Spectrum of **7f** in CDCl<sub>3</sub>



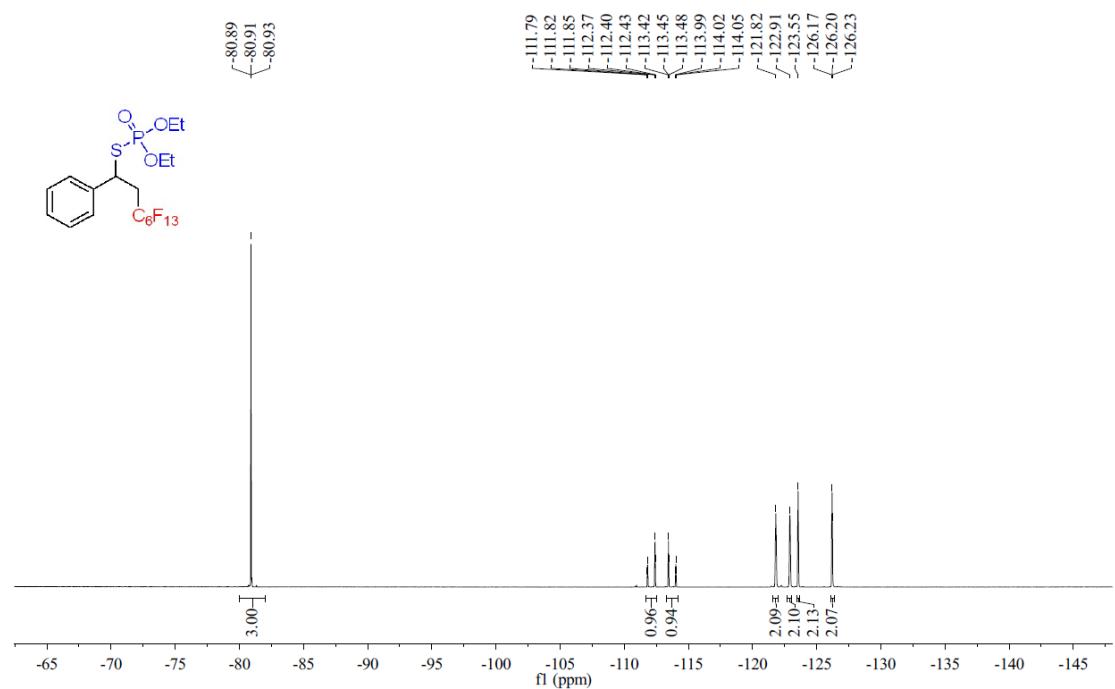
<sup>13</sup>C NMR (151 MHz) Spectrum of **7f** in CDCl<sub>3</sub>



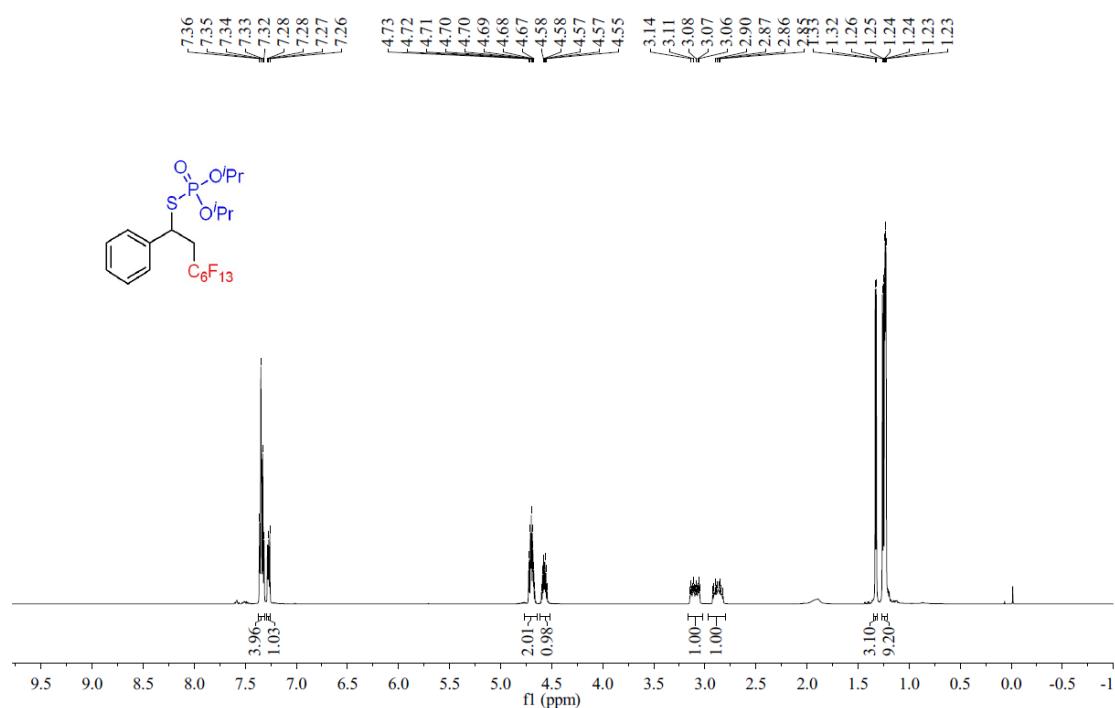
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **7f** in  $\text{CDCl}_3$



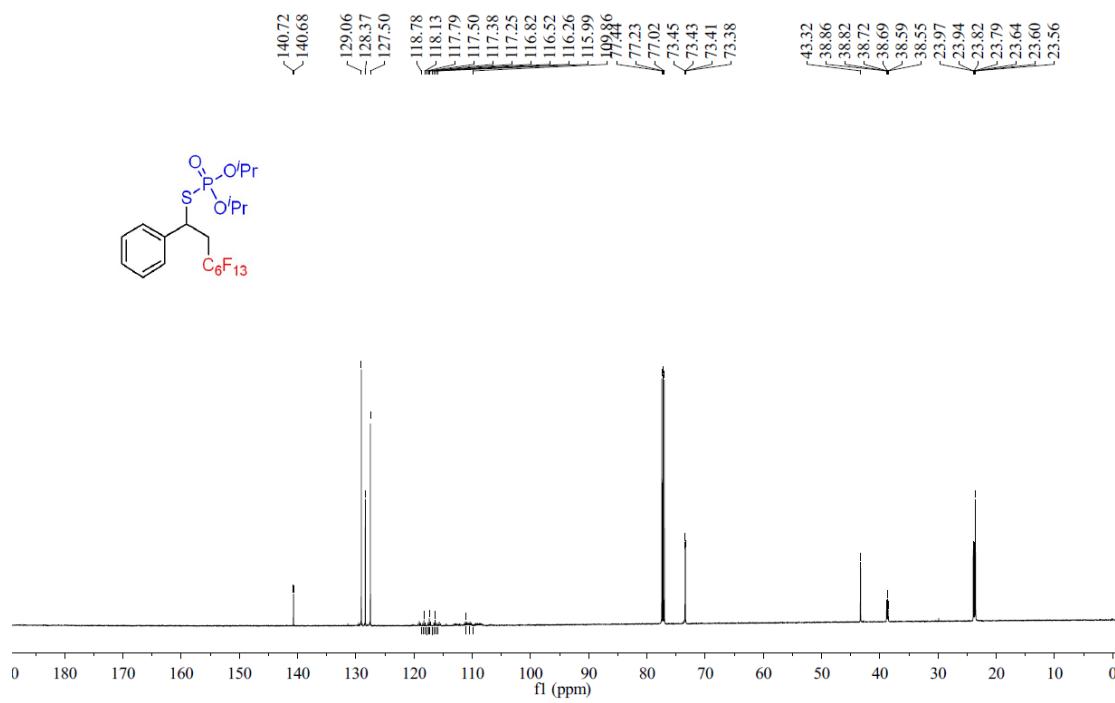
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **7f** in  $\text{CDCl}_3$



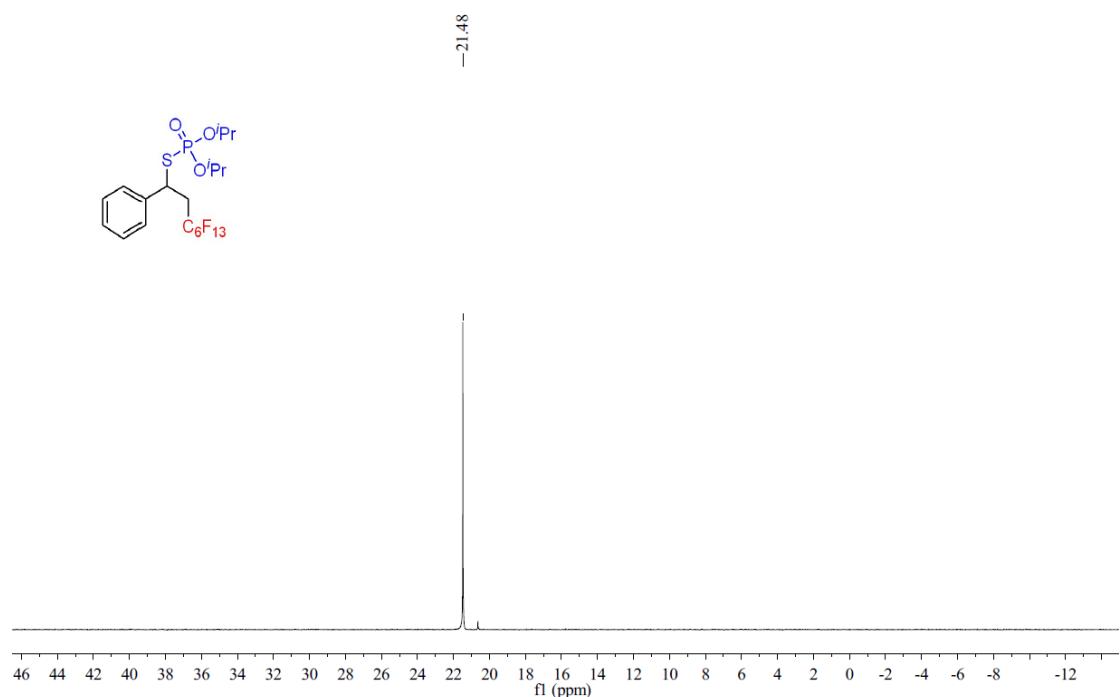
<sup>1</sup>H NMR (400 MHz) Spectrum of **7g** in CDCl<sub>3</sub>



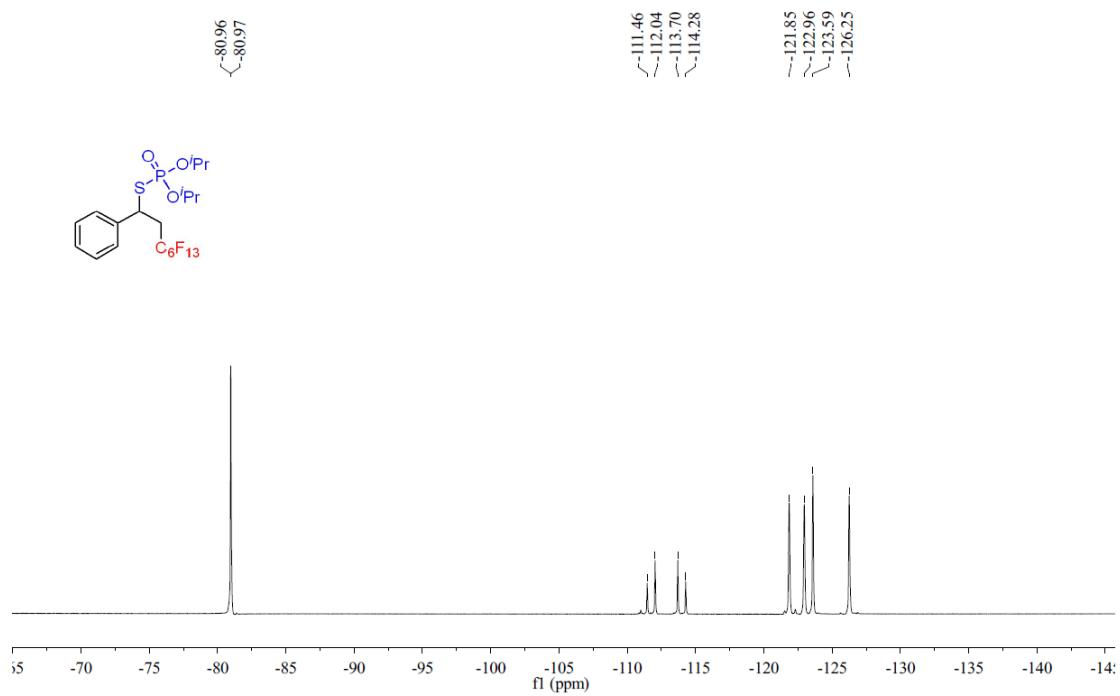
<sup>13</sup>C NMR (151 MHz) Spectrum of **7g** in CDCl<sub>3</sub>



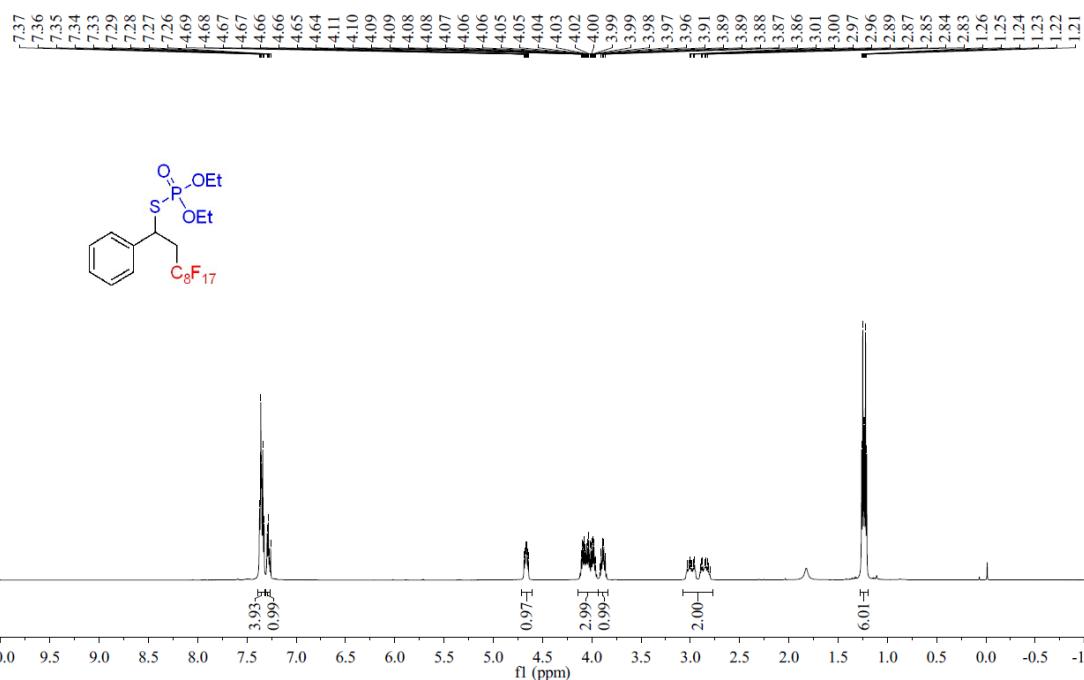
<sup>31</sup>P NMR (243 MHz) Spectrum of **7g** in CDCl<sub>3</sub>



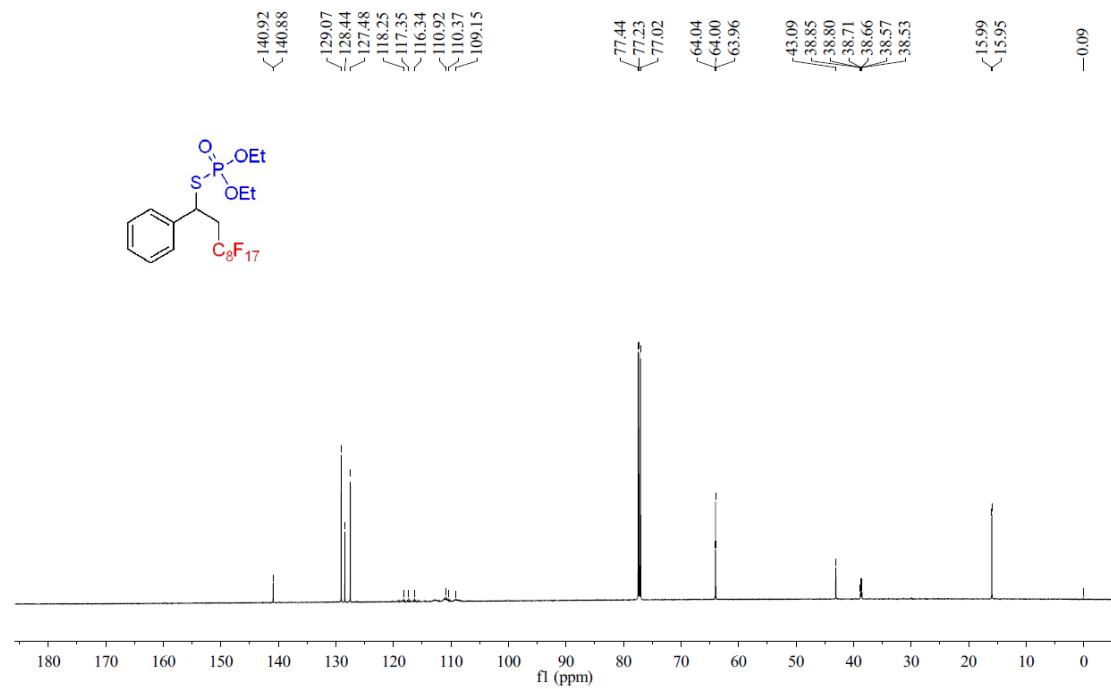
<sup>19</sup>F NMR (471 MHz) Spectrum of **7g** in CDCl<sub>3</sub>



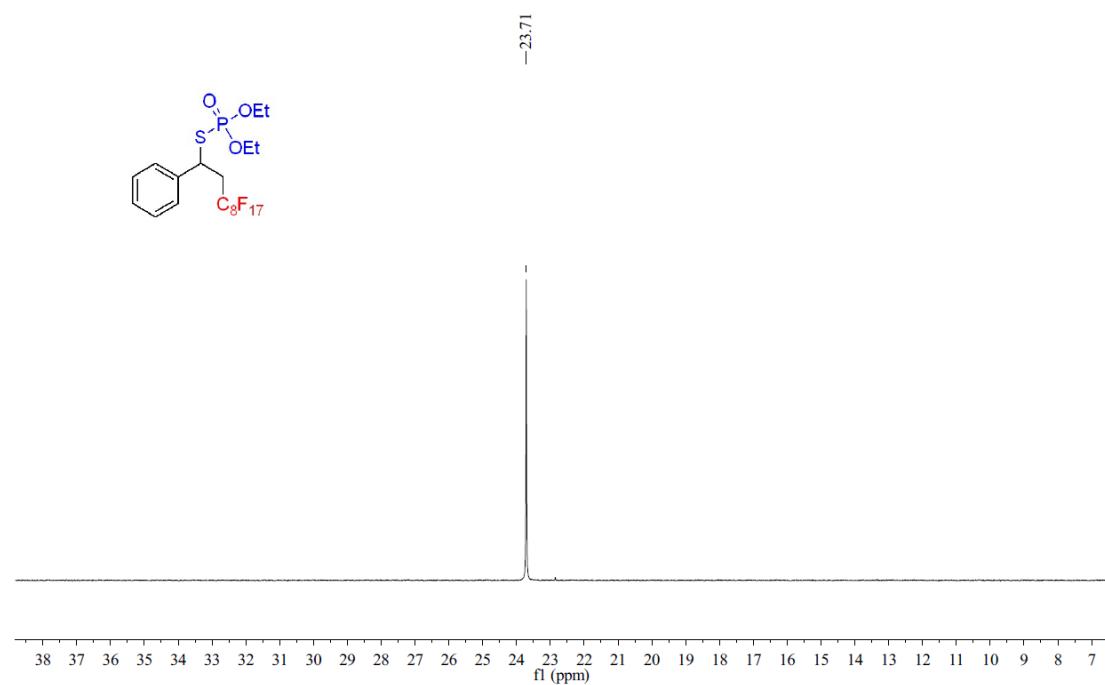
<sup>1</sup>H NMR (400 MHz) Spectrum of **7h** in CDCl<sub>3</sub>



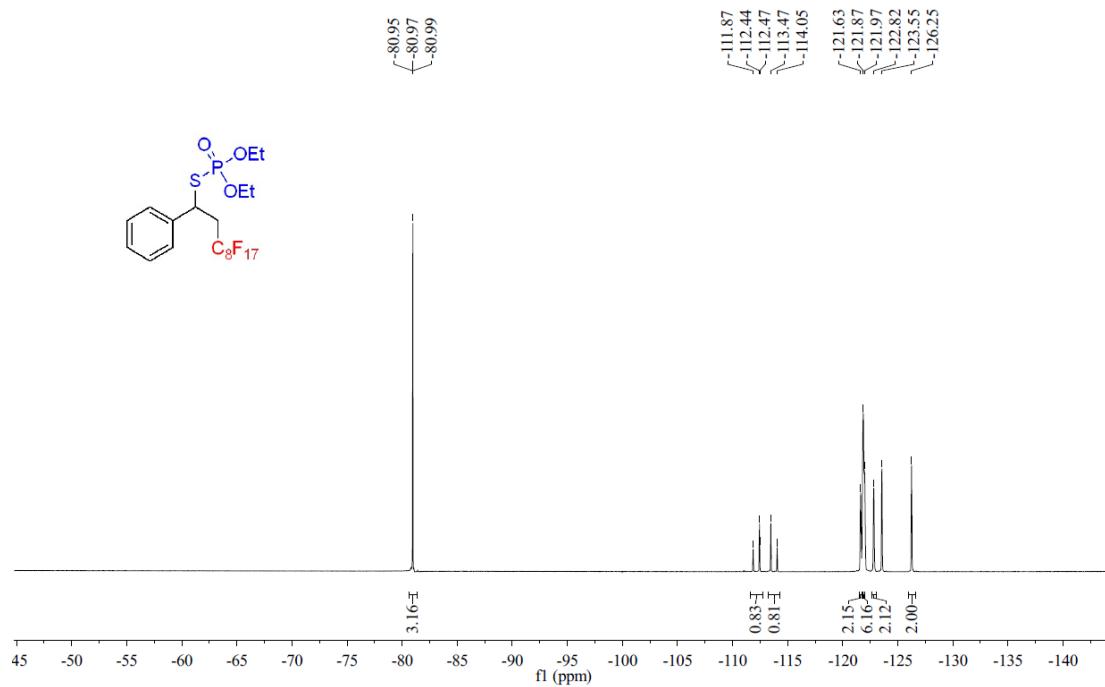
<sup>13</sup>C NMR (151 MHz) Spectrum of **7h** in CDCl<sub>3</sub>



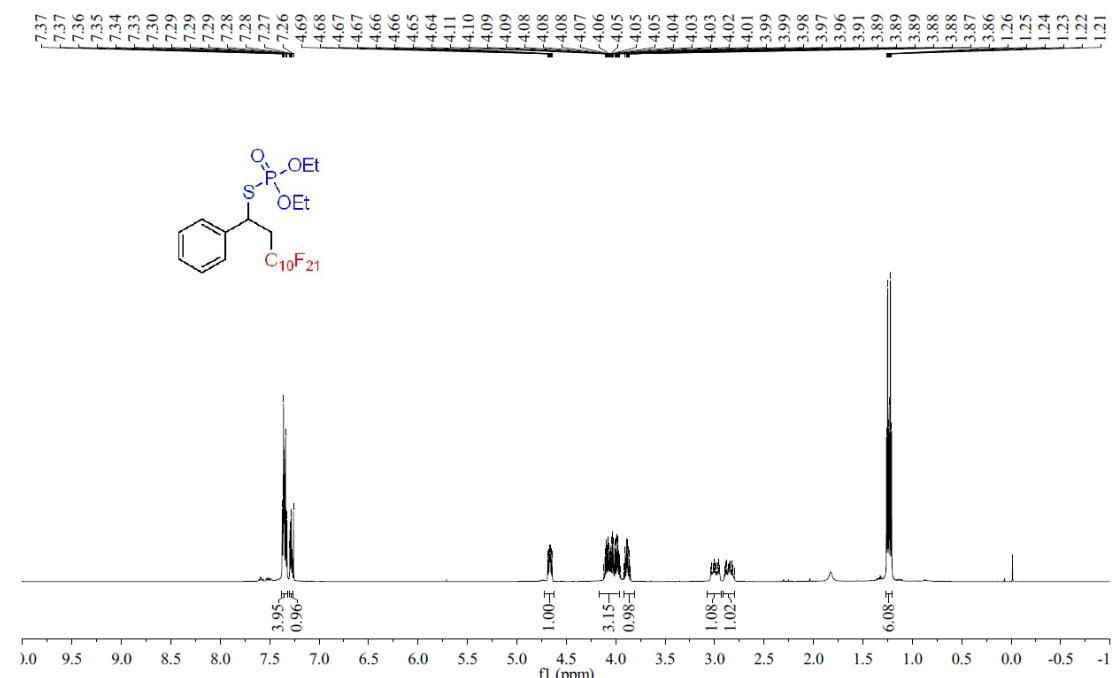
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **7h** in  $\text{CDCl}_3$



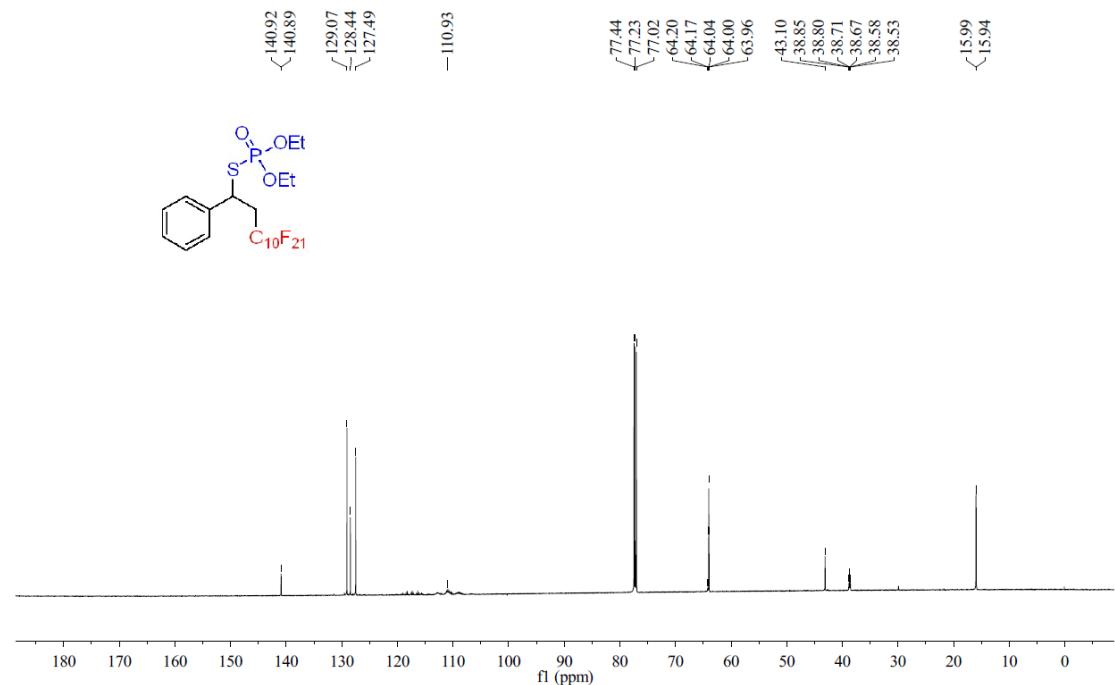
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **7h** in  $\text{CDCl}_3$



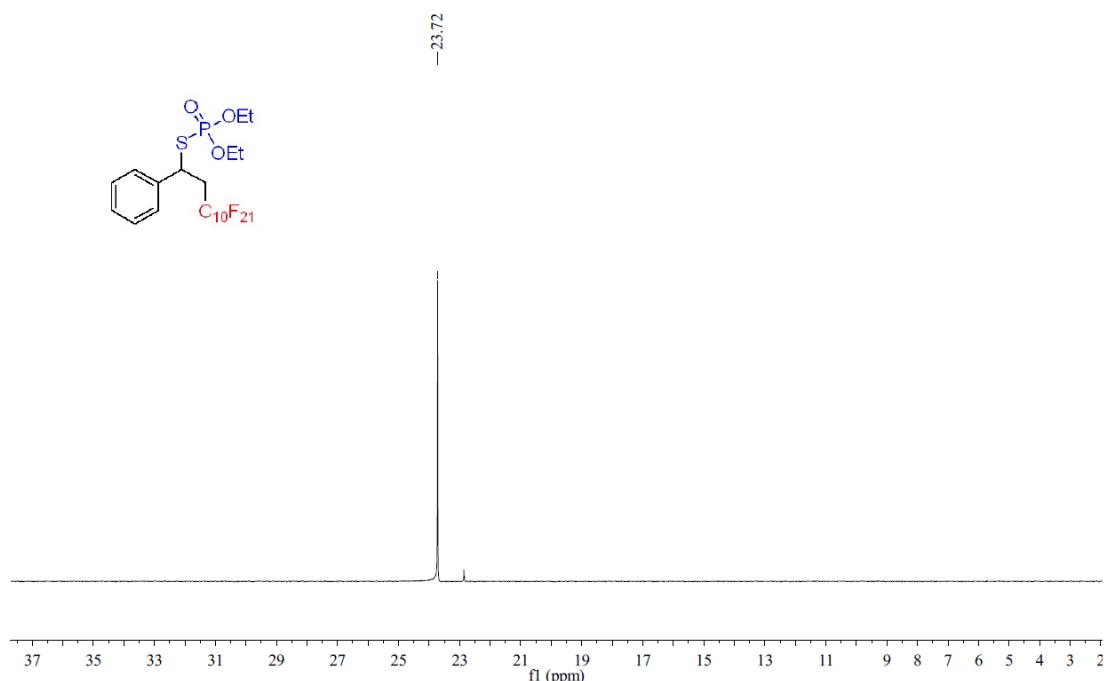
<sup>1</sup>H NMR (400 MHz) Spectrum of **7i** in CDCl<sub>3</sub>



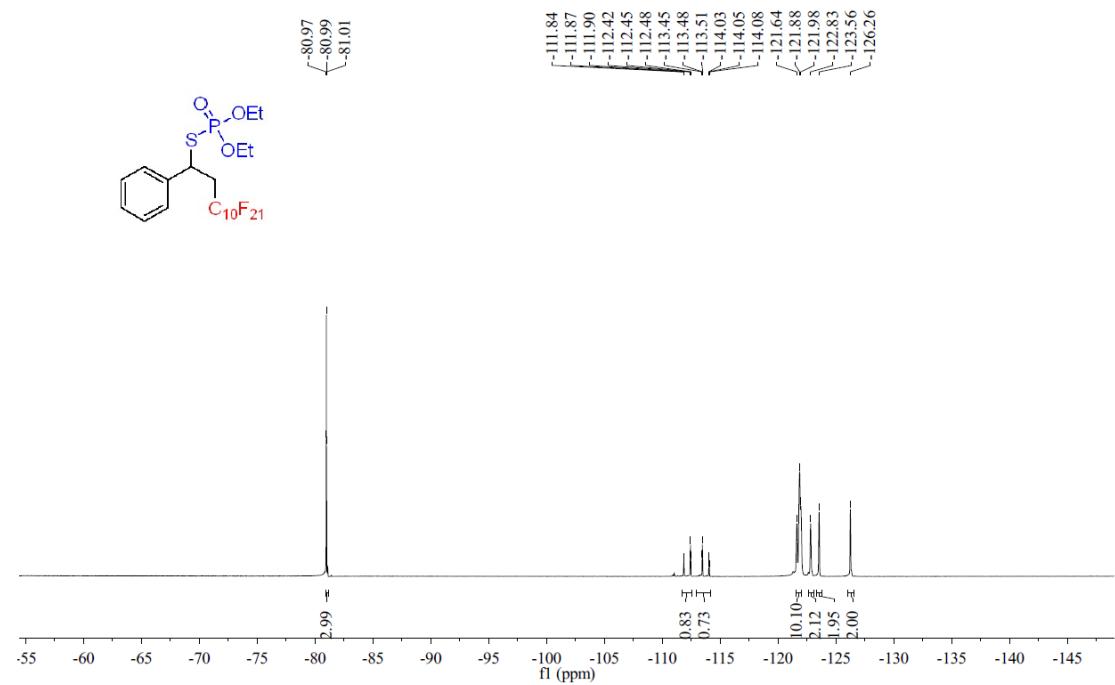
<sup>13</sup>C NMR (151 MHz) Spectrum of **7i** in CDCl<sub>3</sub>



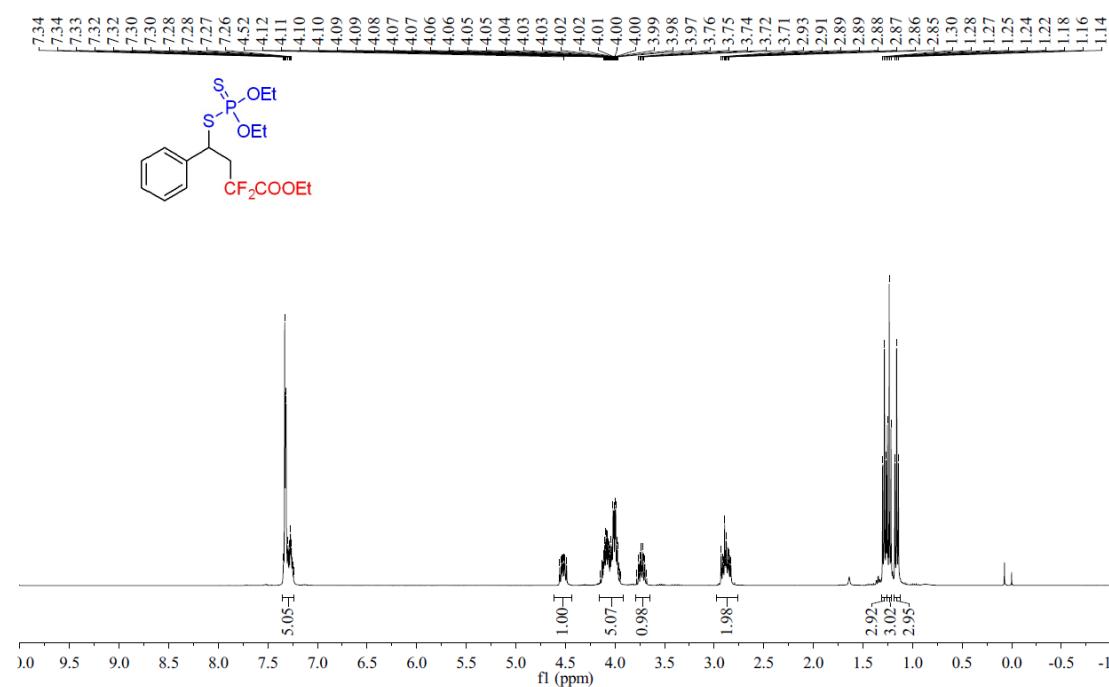
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **7i** in  $\text{CDCl}_3$



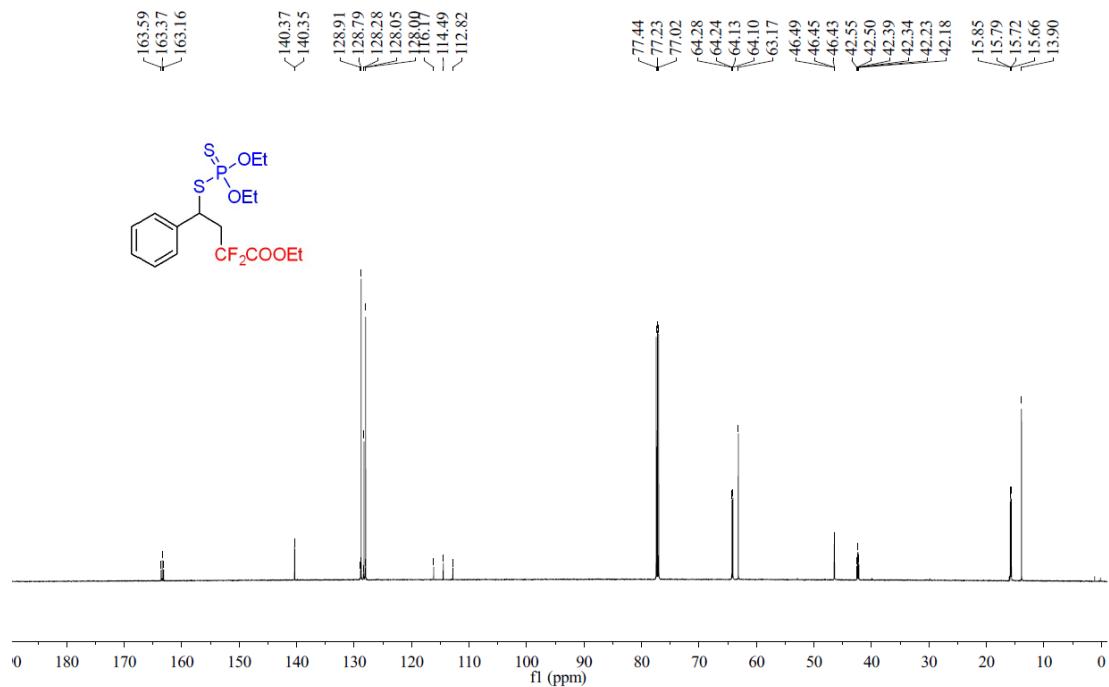
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **7i** in  $\text{CDCl}_3$



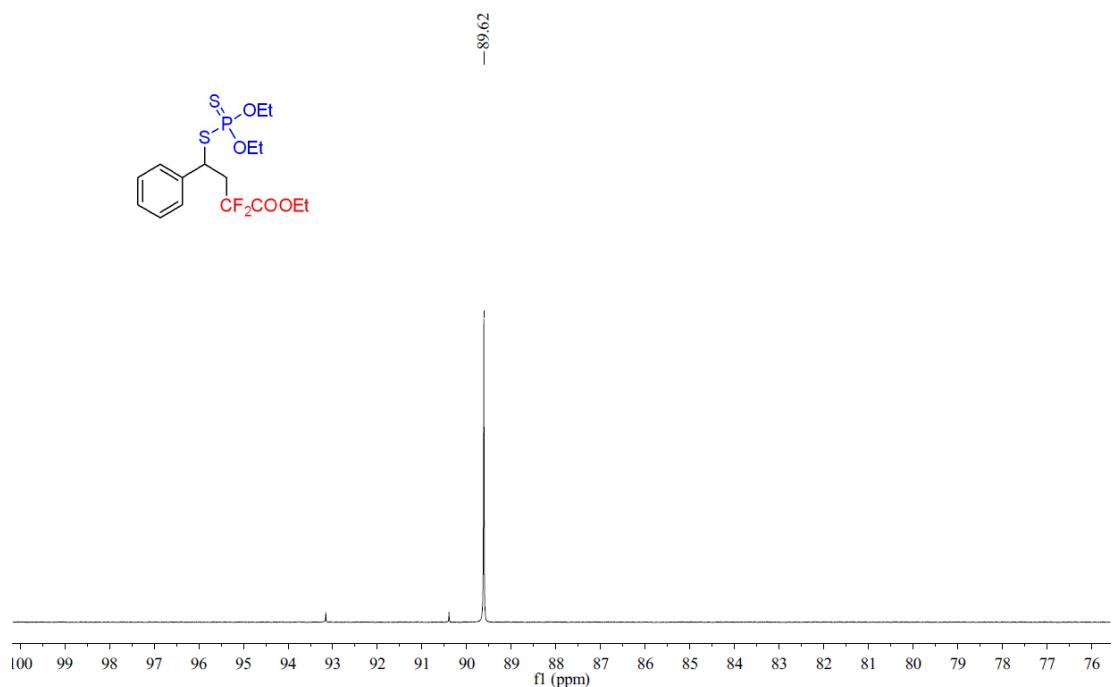
<sup>1</sup>H NMR (400 MHz) Spectrum of **8a** in CDCl<sub>3</sub>



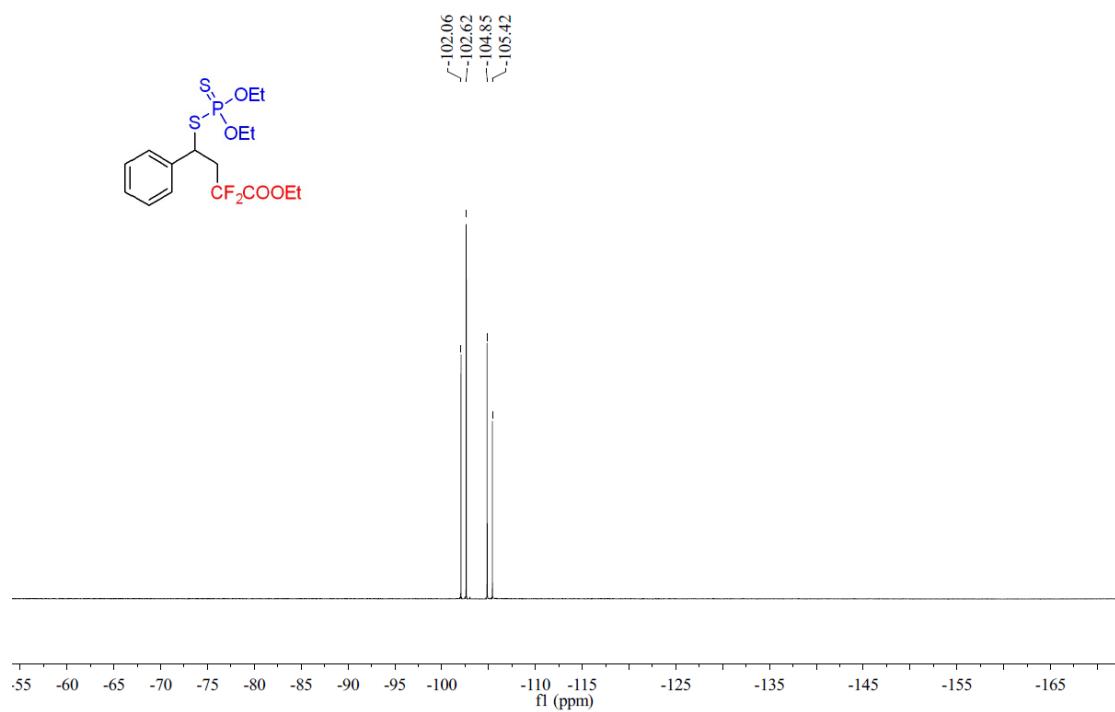
<sup>13</sup>C NMR (151 MHz) Spectrum of **8a** in CDCl<sub>3</sub>



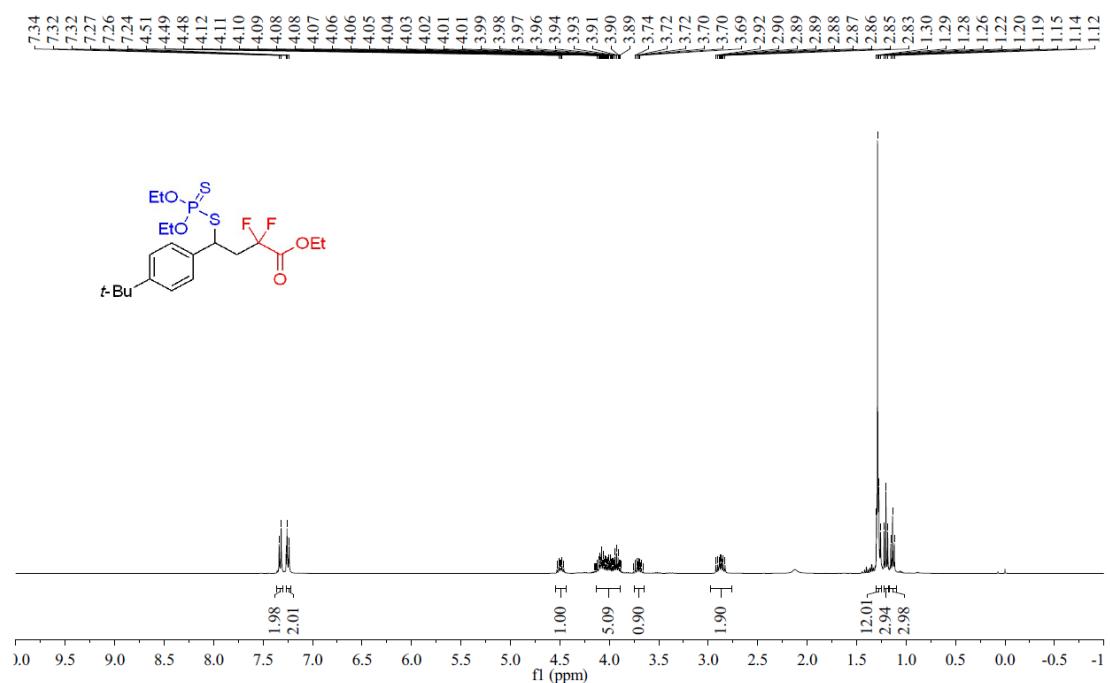
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **8a** in  $\text{CDCl}_3$



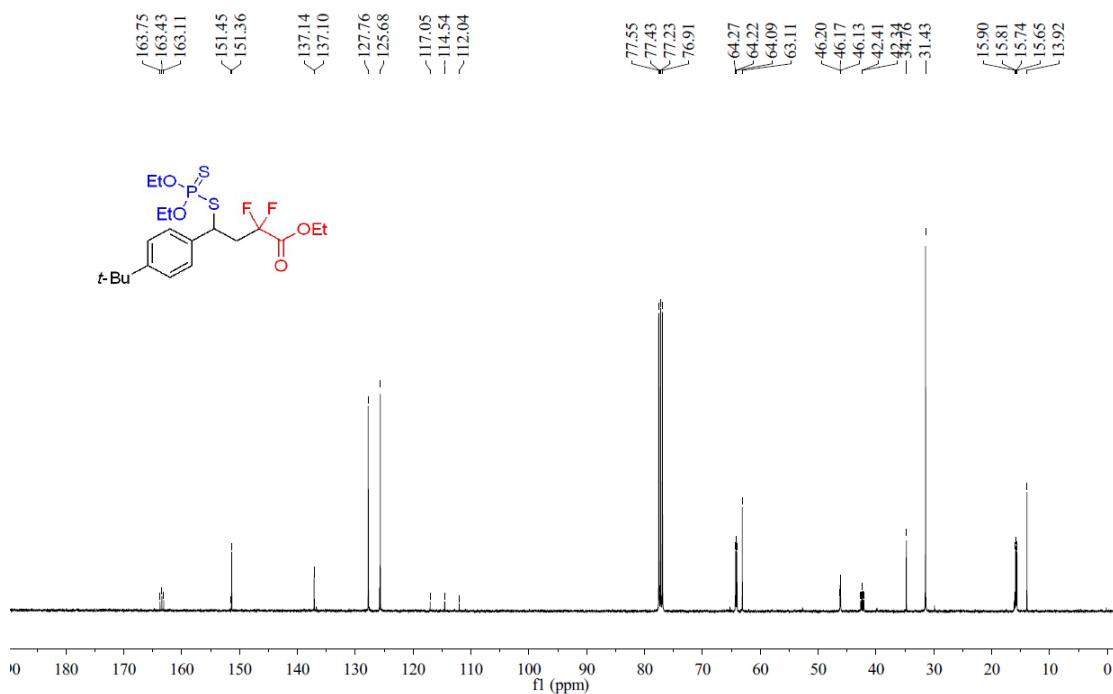
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **8a** in  $\text{CDCl}_3$



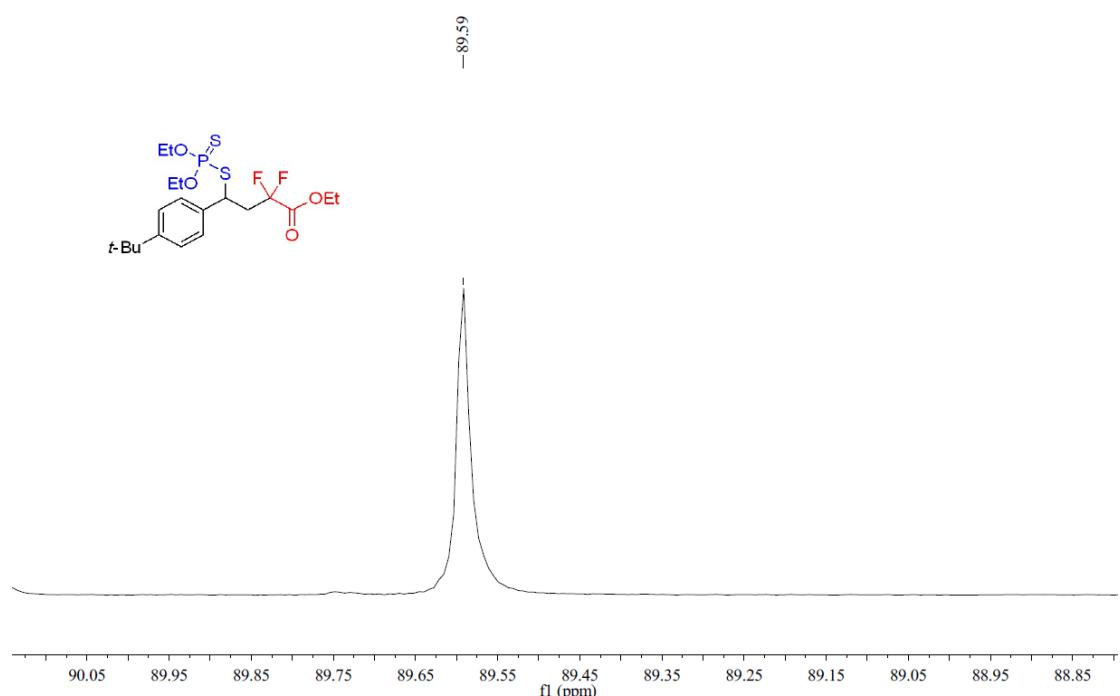
<sup>1</sup>H NMR (400 MHz) Spectrum of **8b** in CDCl<sub>3</sub>



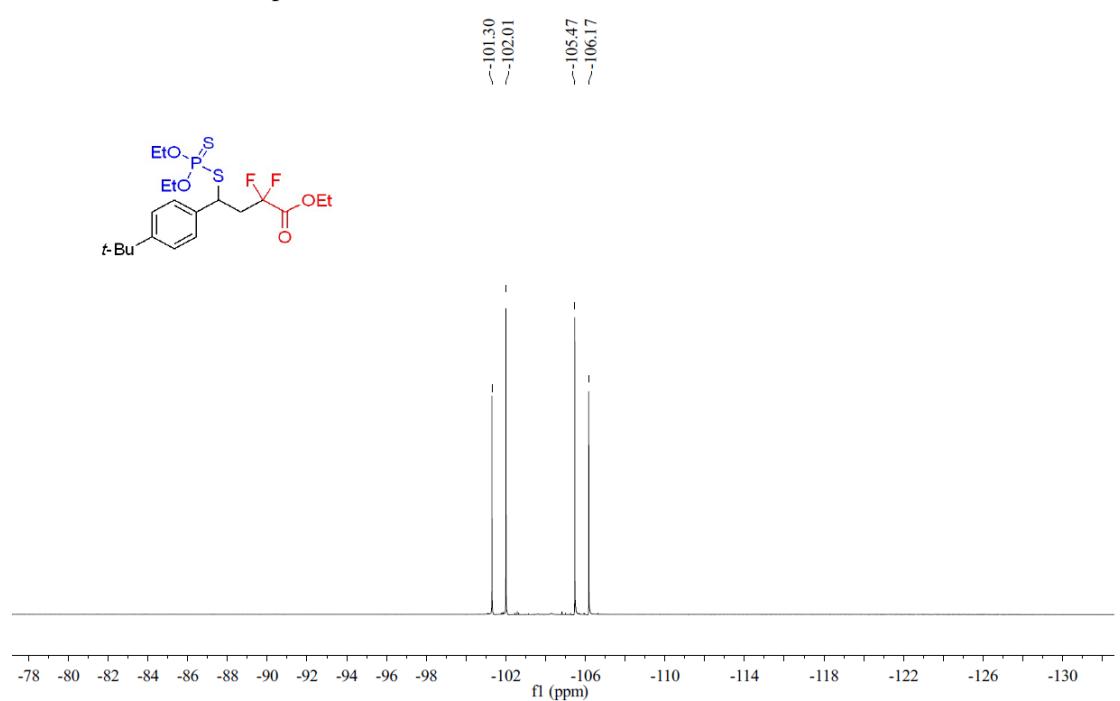
<sup>13</sup>C NMR (151 MHz) Spectrum of **8b** in CDCl<sub>3</sub>



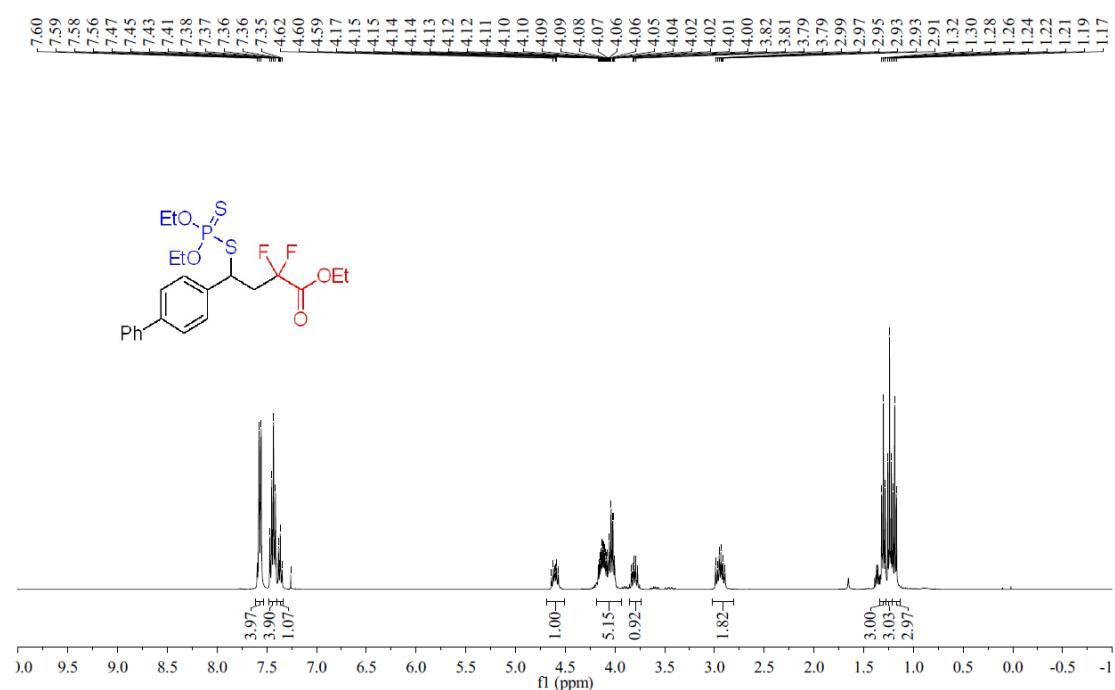
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **8b** in  $\text{CDCl}_3$



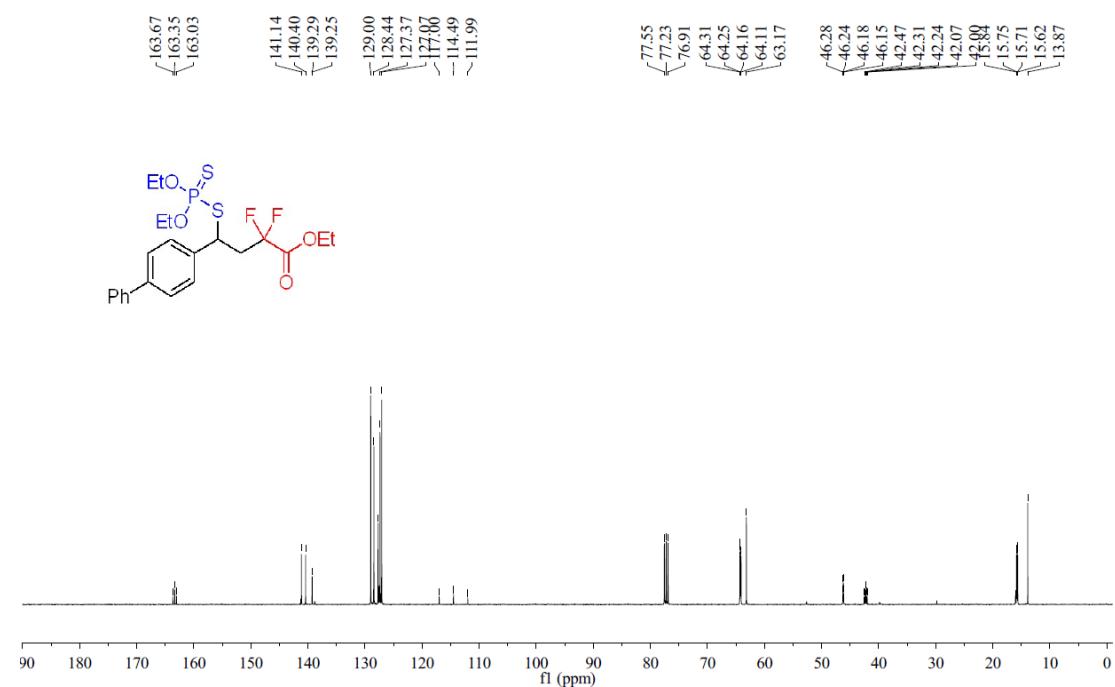
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **8b** in  $\text{CDCl}_3$



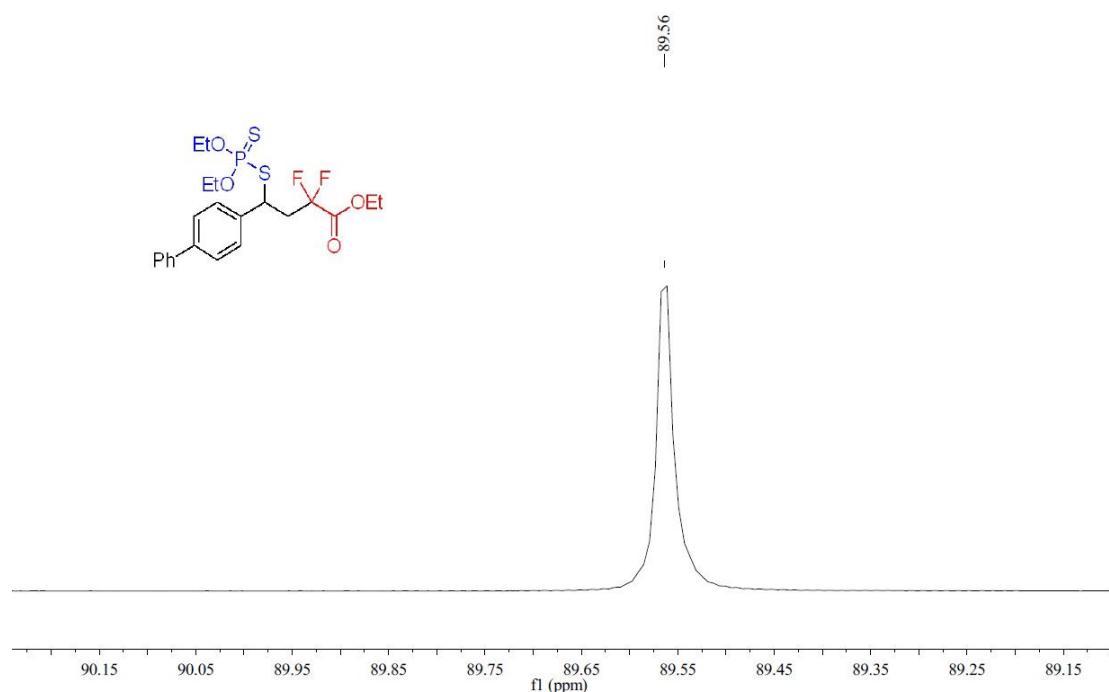
<sup>1</sup>H NMR (400 MHz) Spectrum of **8c** in CDCl<sub>3</sub>



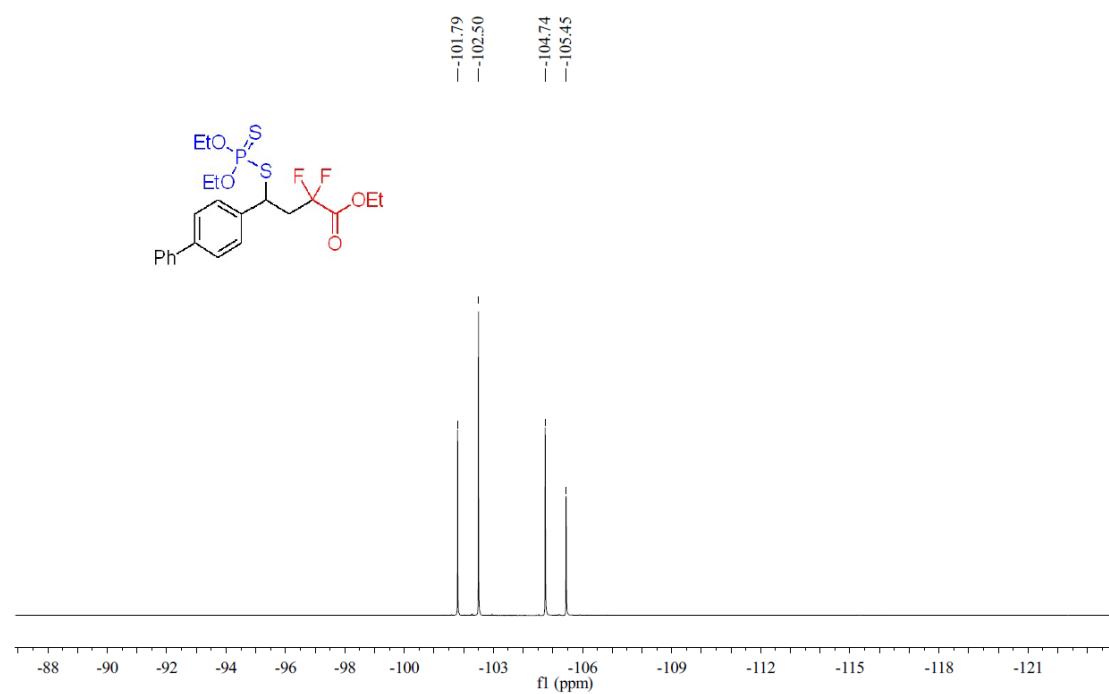
<sup>13</sup>C NMR (151 MHz) Spectrum of **8c** in CDCl<sub>3</sub>



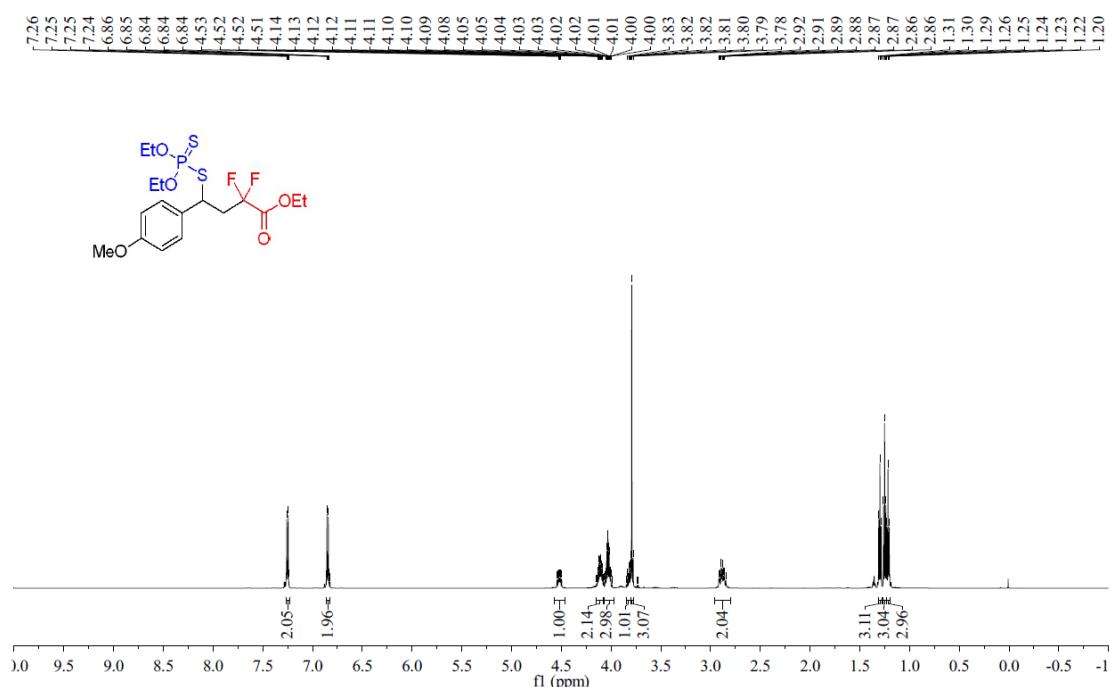
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **8c** in  $\text{CDCl}_3$



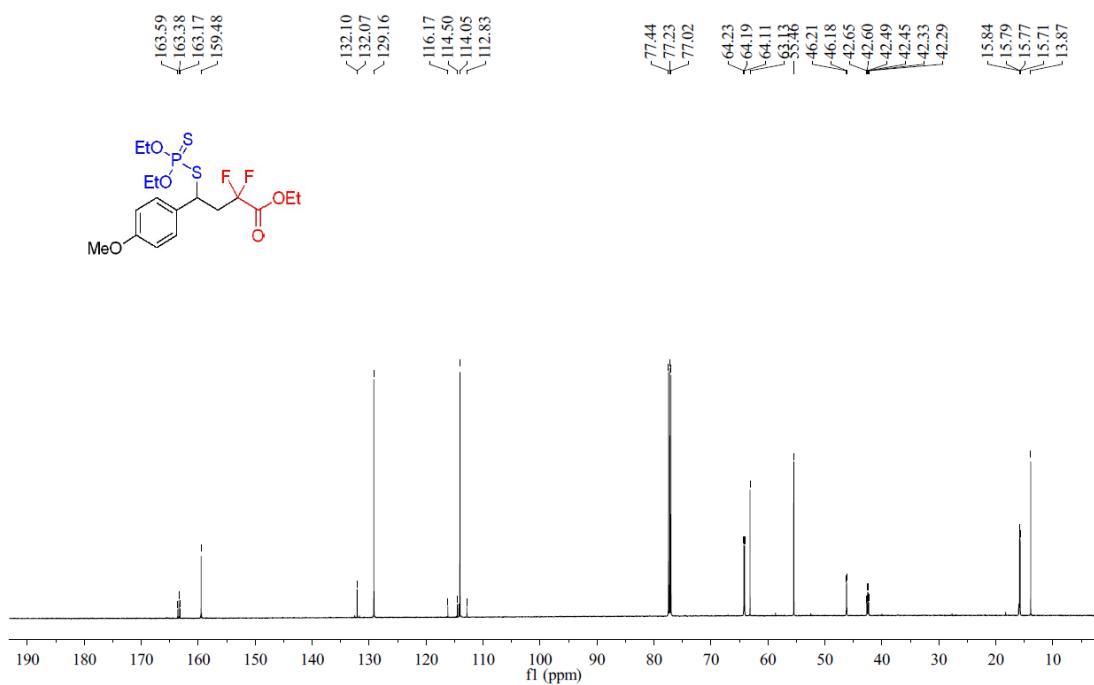
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **8c** in  $\text{CDCl}_3$



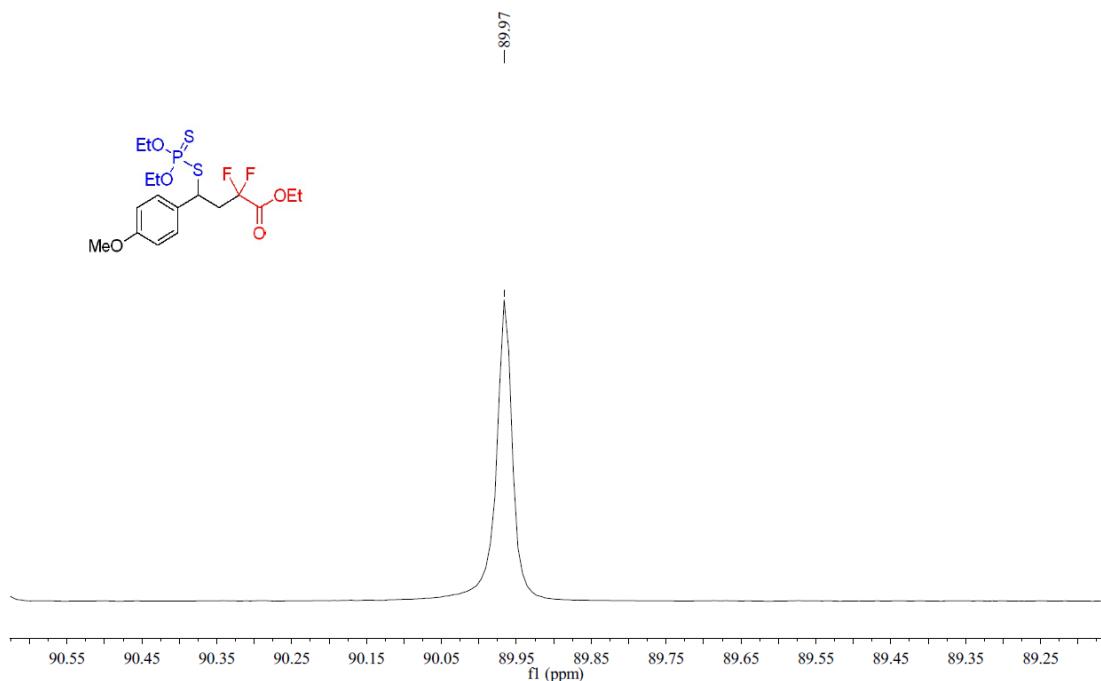
<sup>1</sup>H NMR (400 MHz) Spectrum of **8d** in CDCl<sub>3</sub>



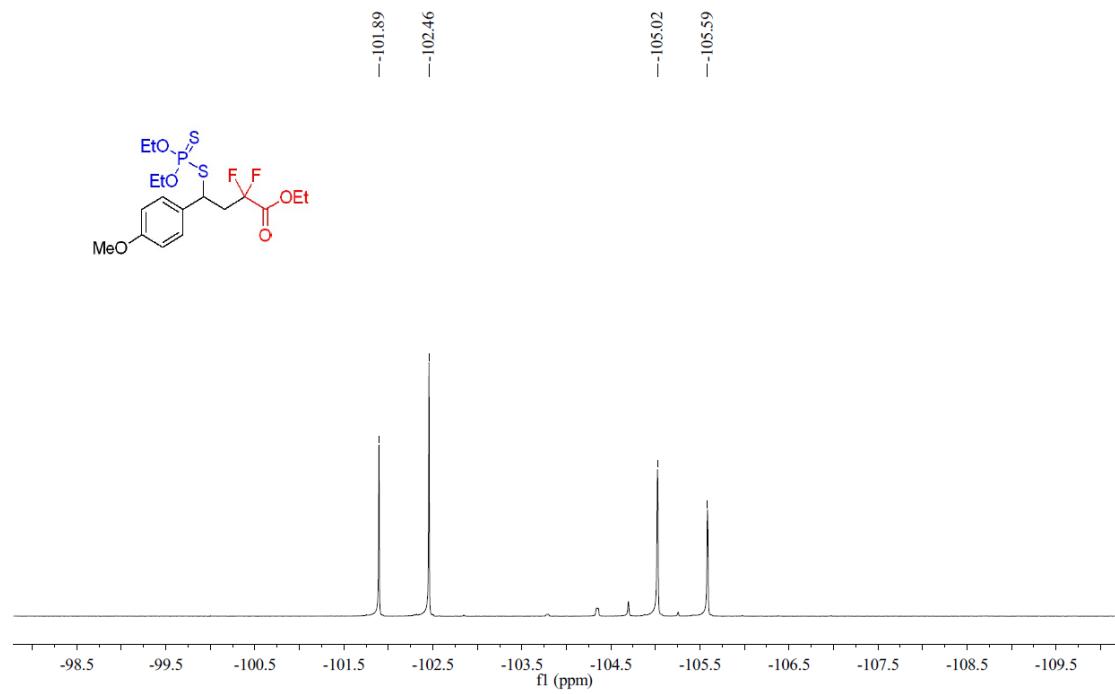
<sup>13</sup>C NMR (151 MHz) Spectrum of **8d** in CDCl<sub>3</sub>



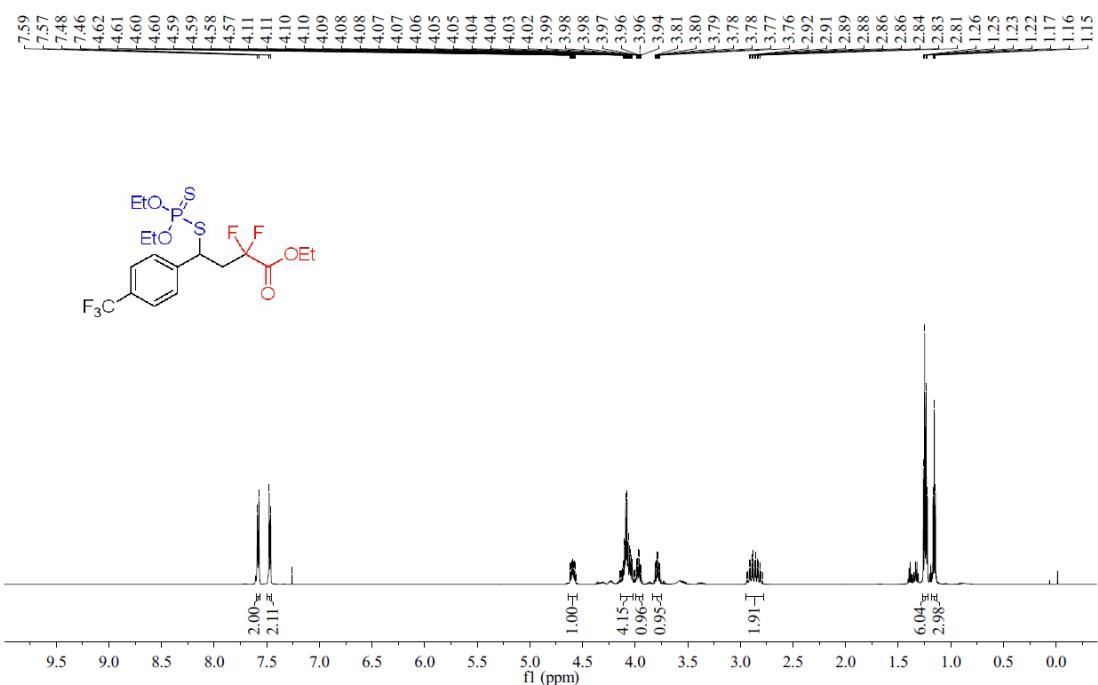
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **8d** in  $\text{CDCl}_3$



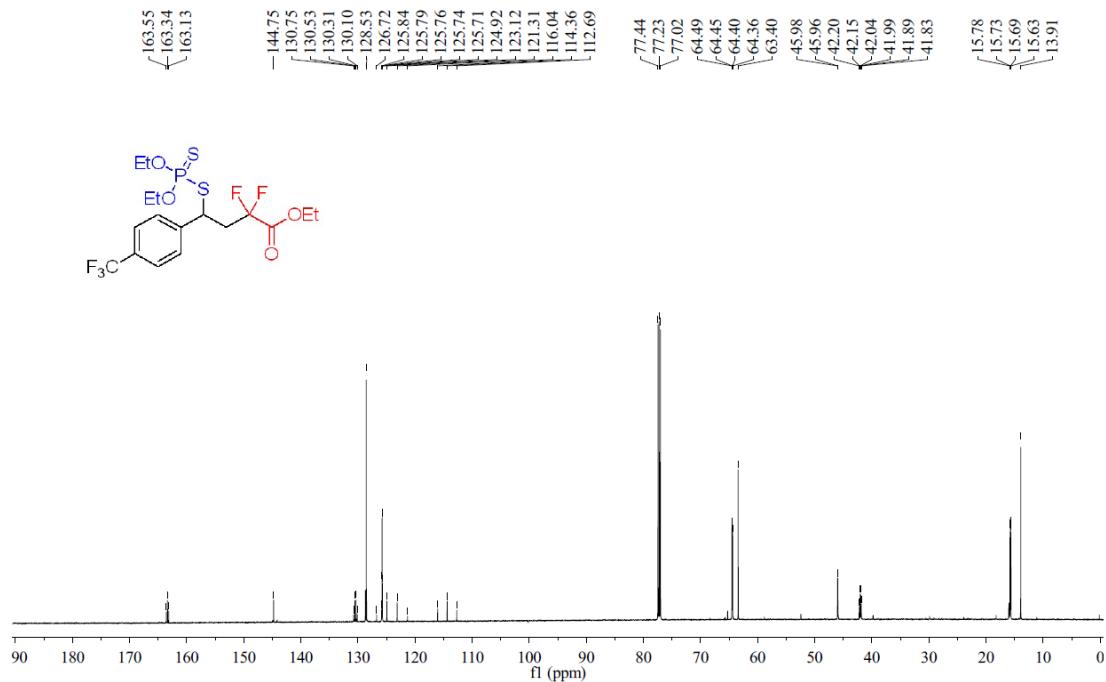
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **8d** in  $\text{CDCl}_3$



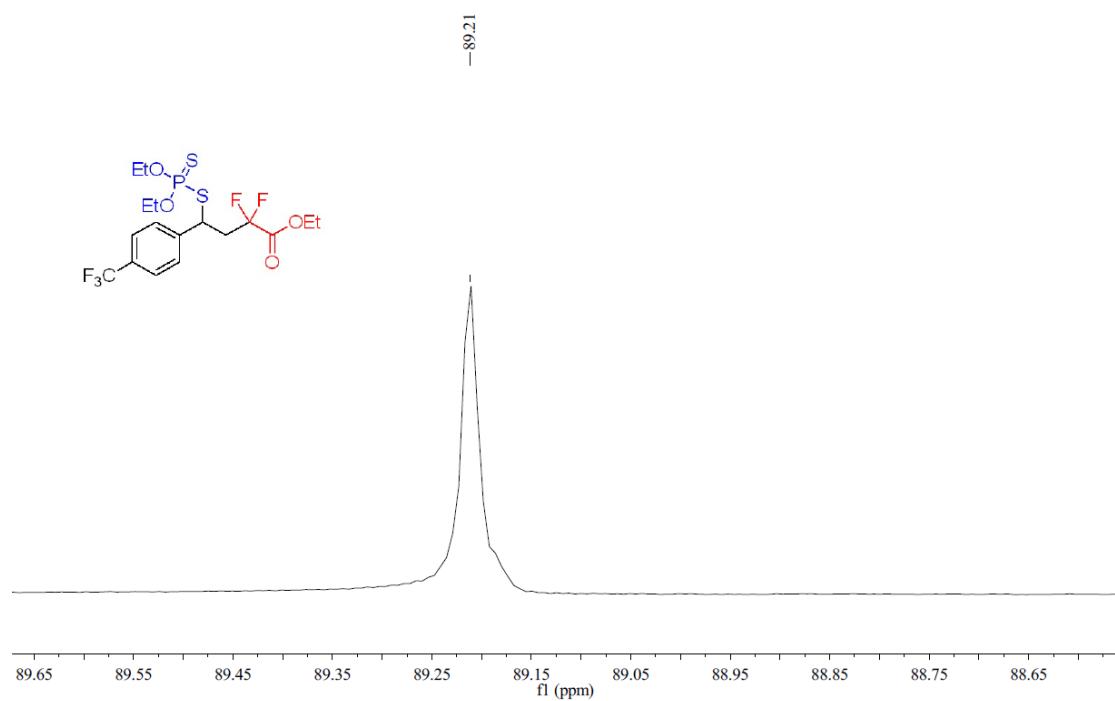
<sup>1</sup>H NMR (400 MHz) Spectrum of **8e** in CDCl<sub>3</sub>



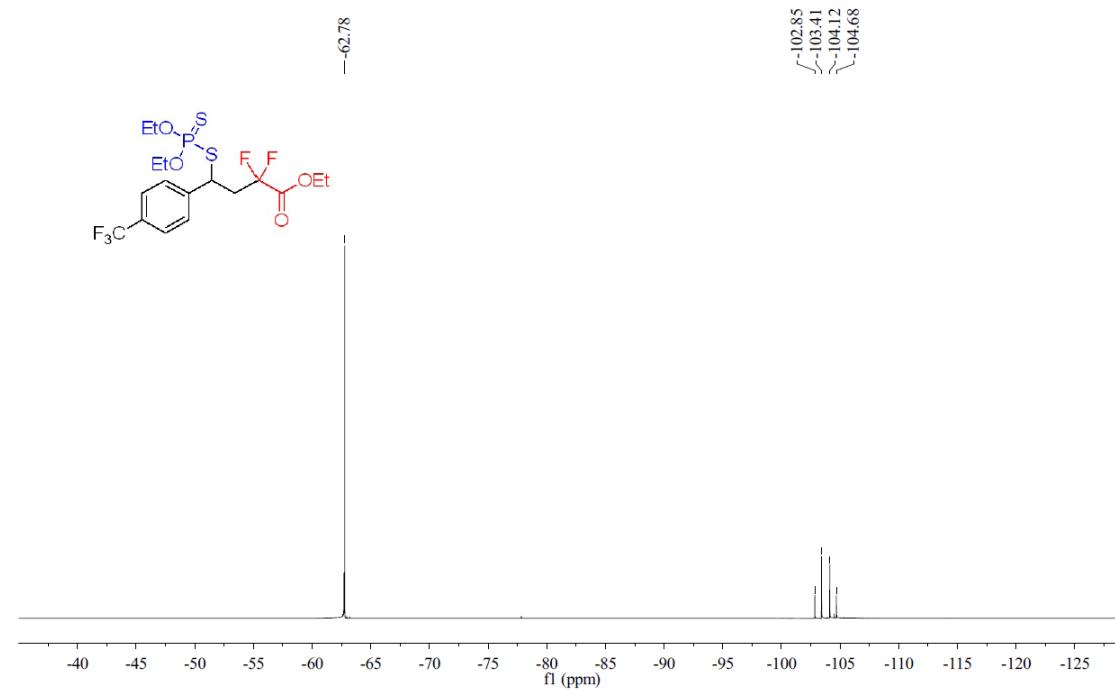
<sup>13</sup>C NMR (151 MHz) Spectrum of **8e** in CDCl<sub>3</sub>



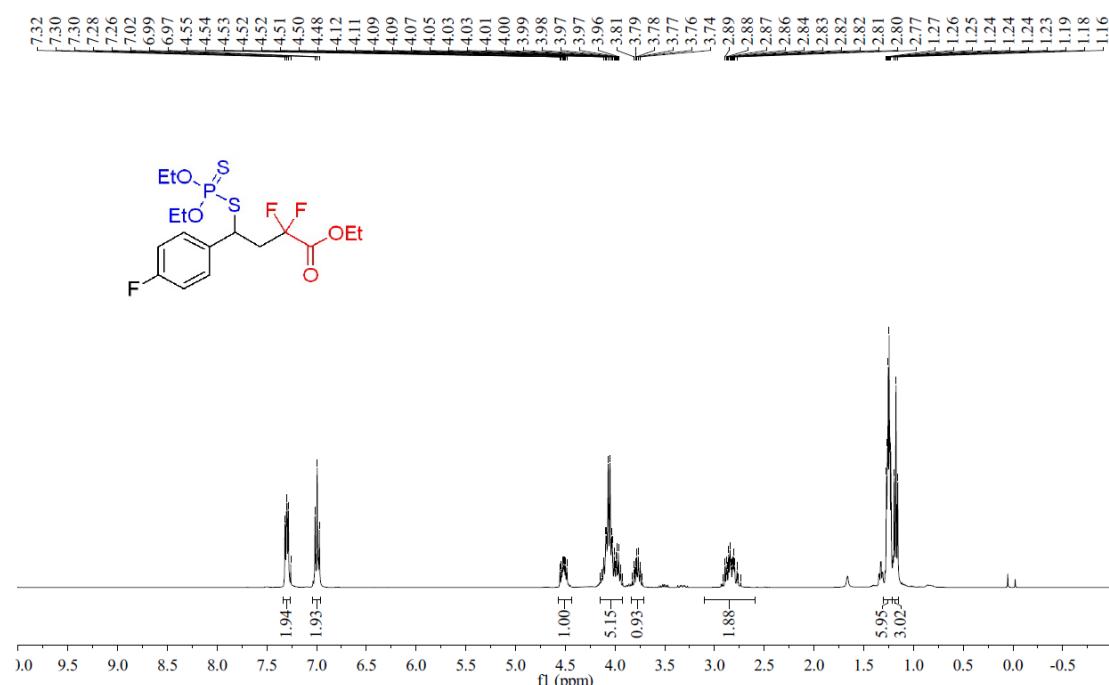
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **8e** in  $\text{CDCl}_3$



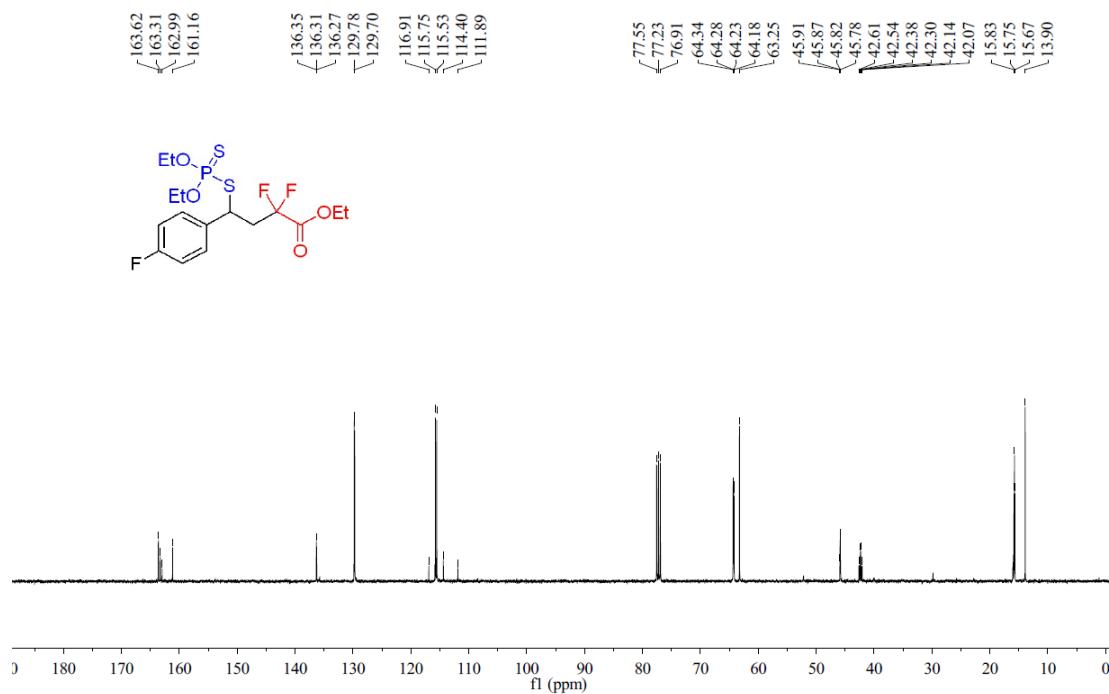
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **8e** in  $\text{CDCl}_3$



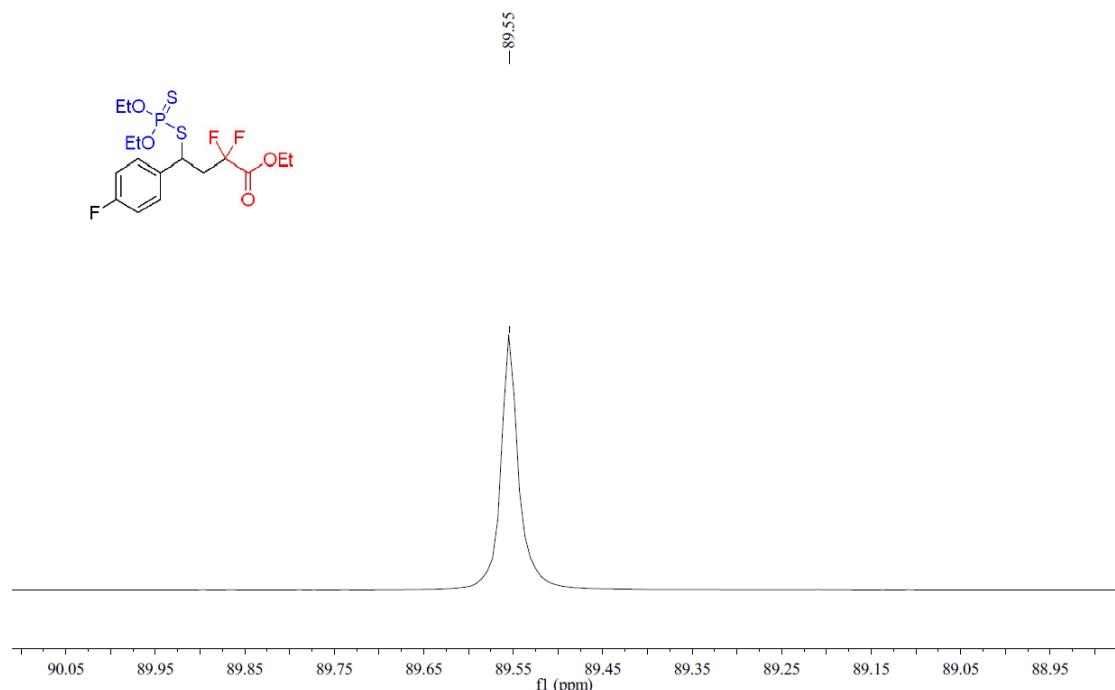
<sup>1</sup>H NMR (400 MHz) Spectrum of **8f** in CDCl<sub>3</sub>



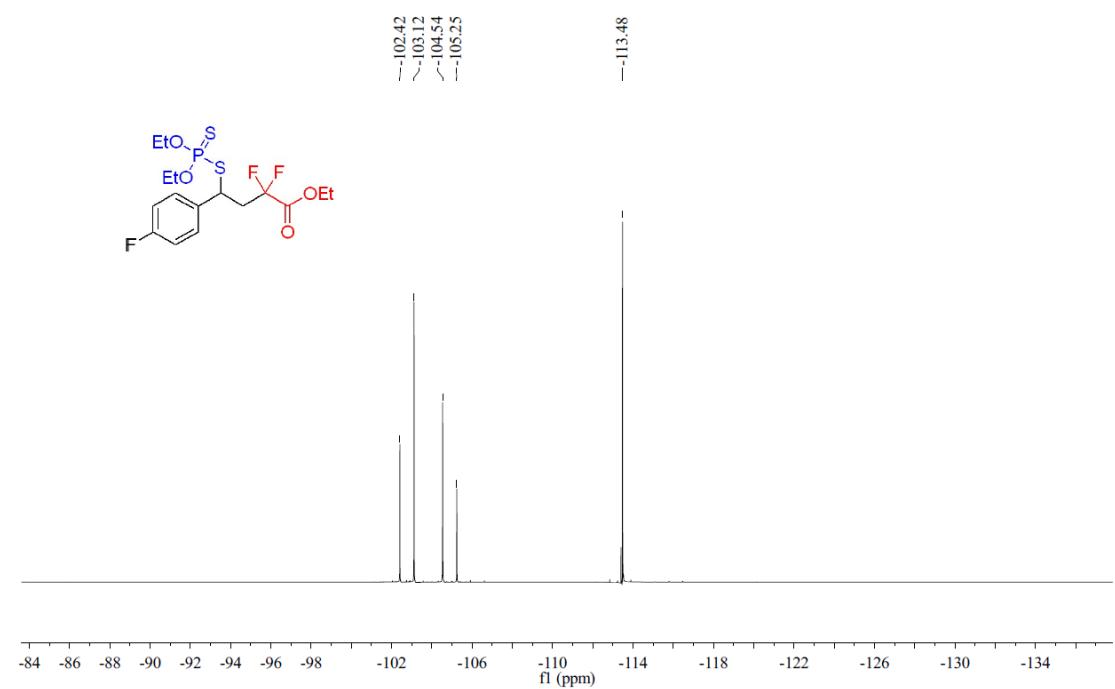
<sup>13</sup>C NMR (151 MHz) Spectrum of **8f** in CDCl<sub>3</sub>



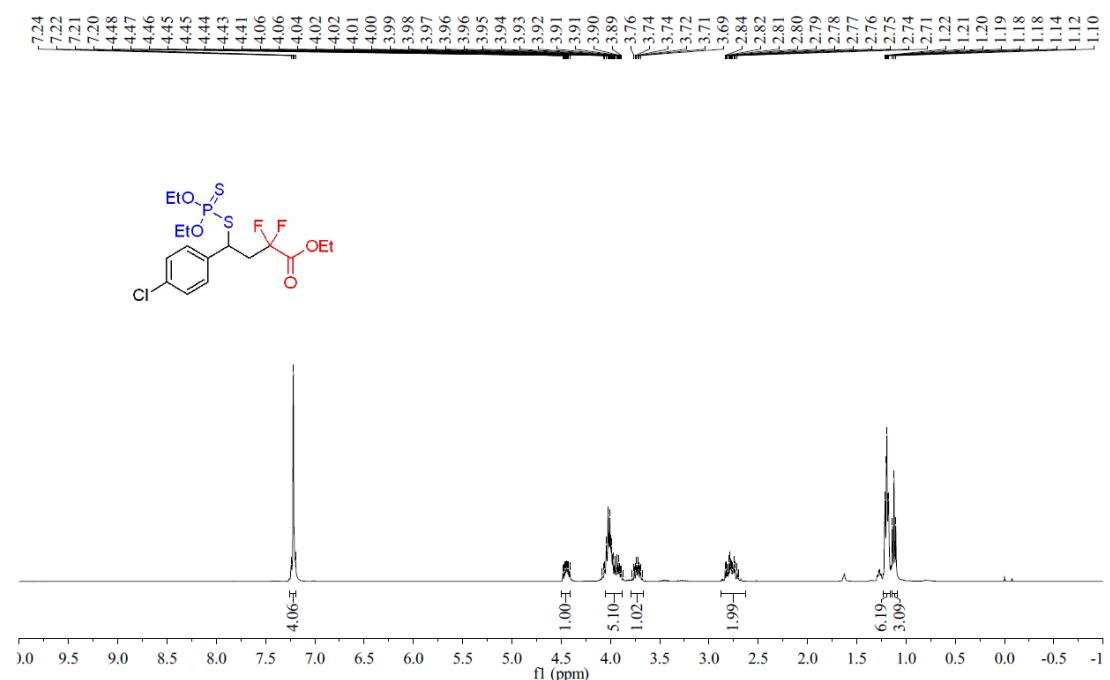
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **8f** in  $\text{CDCl}_3$



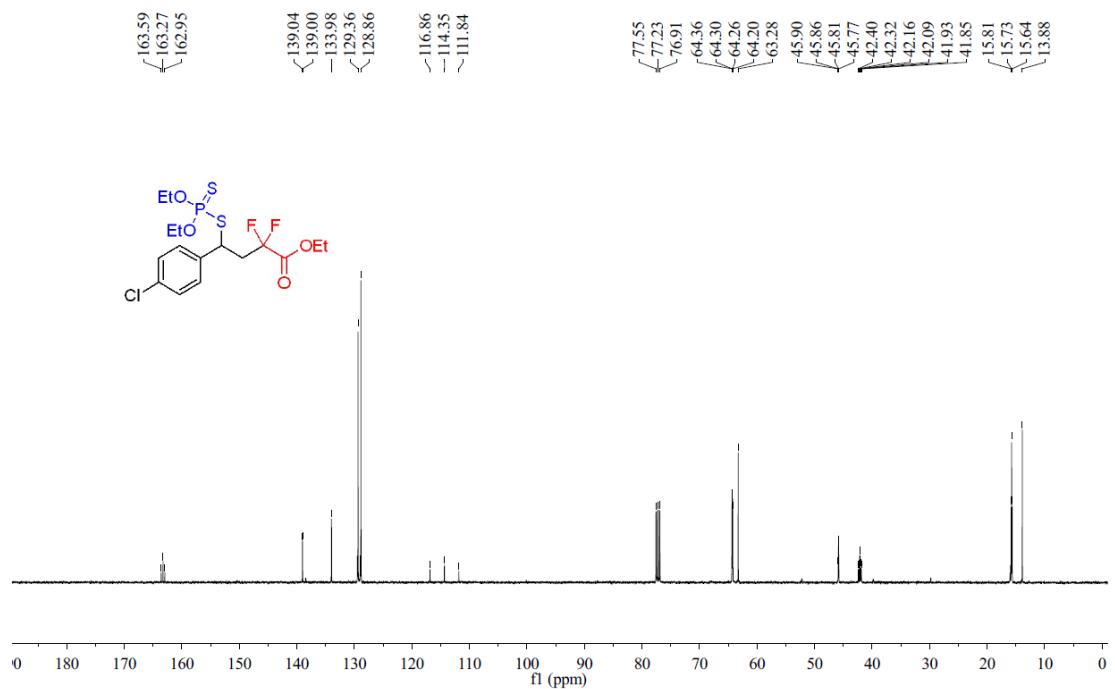
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **8f** in  $\text{CDCl}_3$



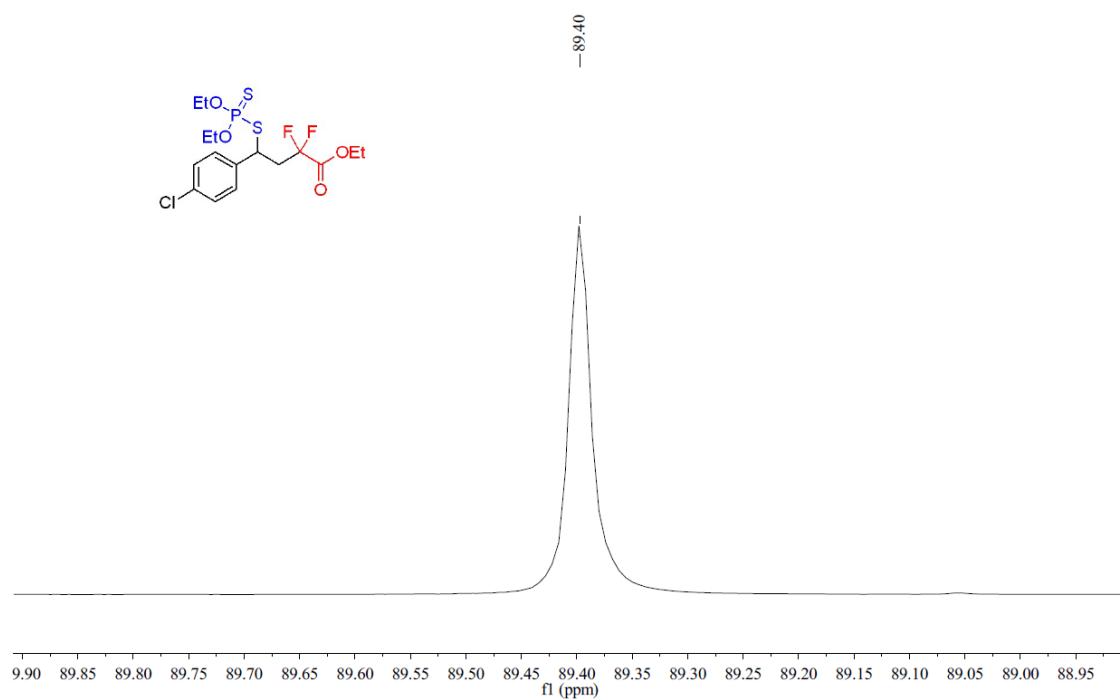
<sup>1</sup>H NMR (400 MHz) Spectrum of **8g** in CDCl<sub>3</sub>



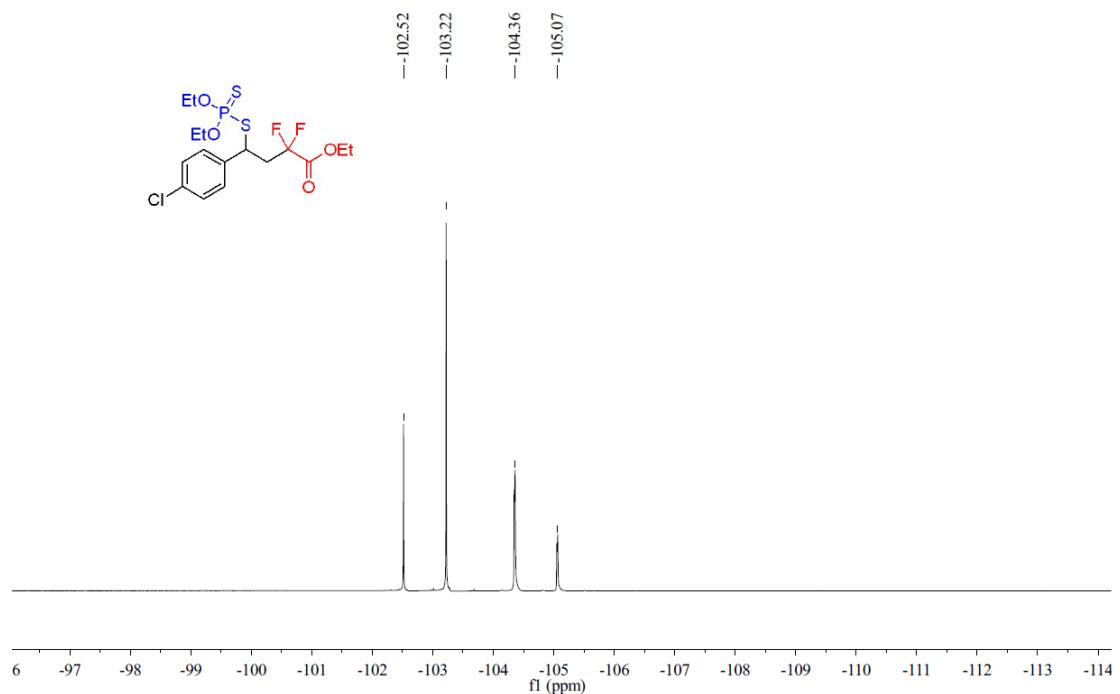
<sup>13</sup>C NMR (151 MHz) Spectrum of **8g** in CDCl<sub>3</sub>



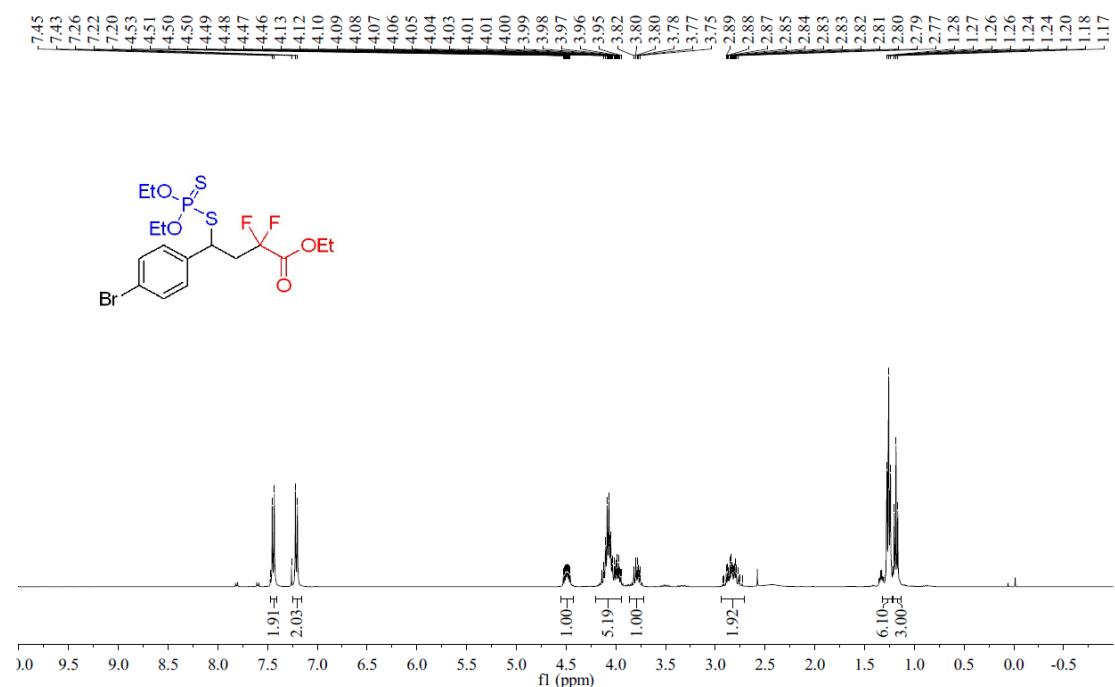
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **8g** in  $\text{CDCl}_3$



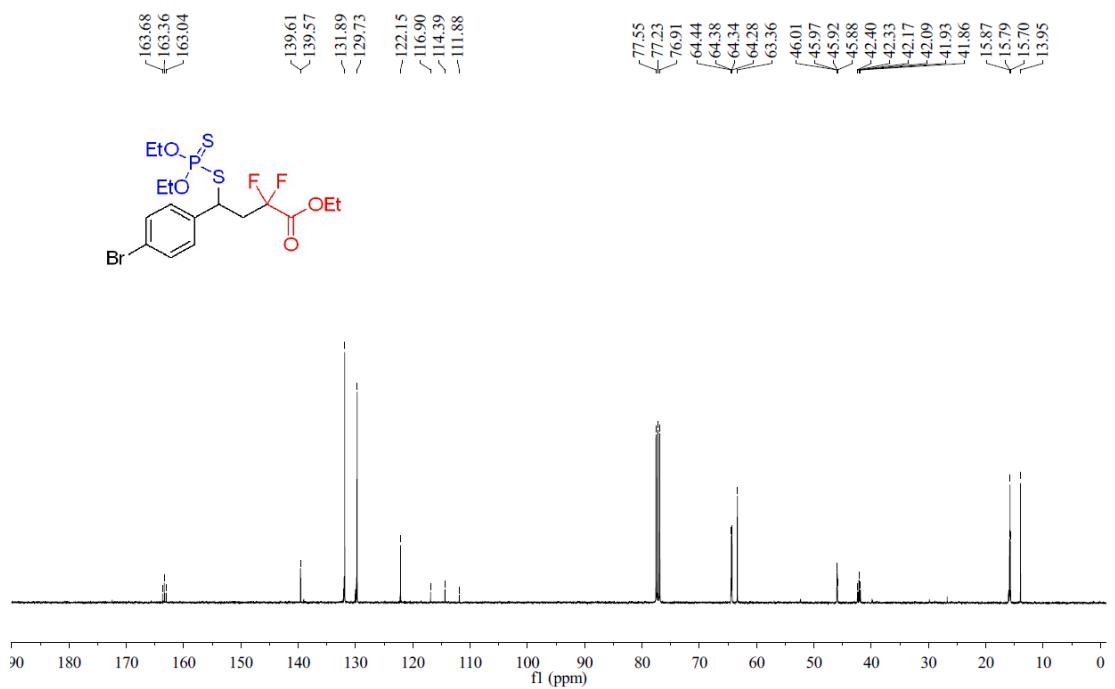
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **8g** in  $\text{CDCl}_3$



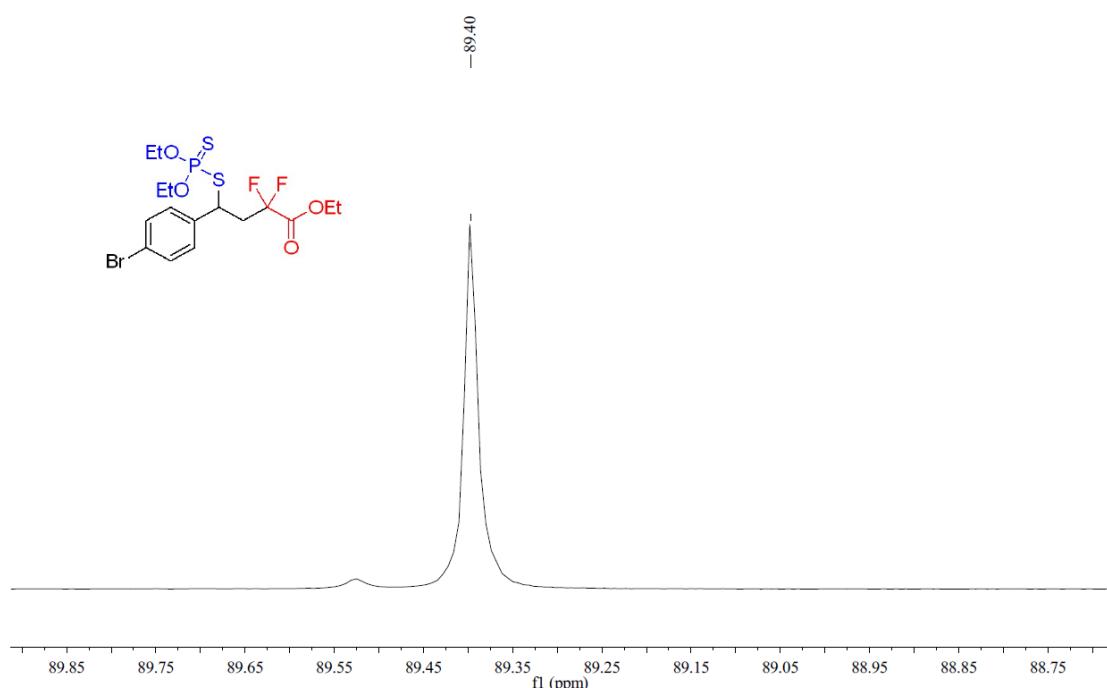
<sup>1</sup>H NMR (400 MHz) Spectrum of **8h** in CDCl<sub>3</sub>



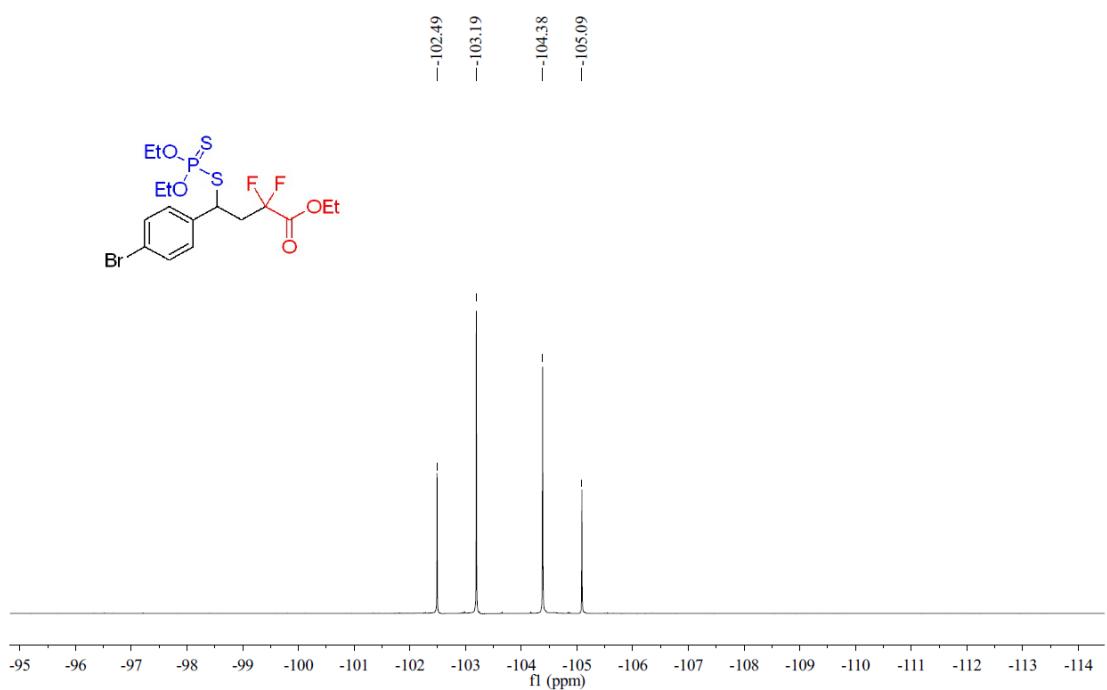
<sup>13</sup>C NMR (151 MHz) Spectrum of **8h** in CDCl<sub>3</sub>



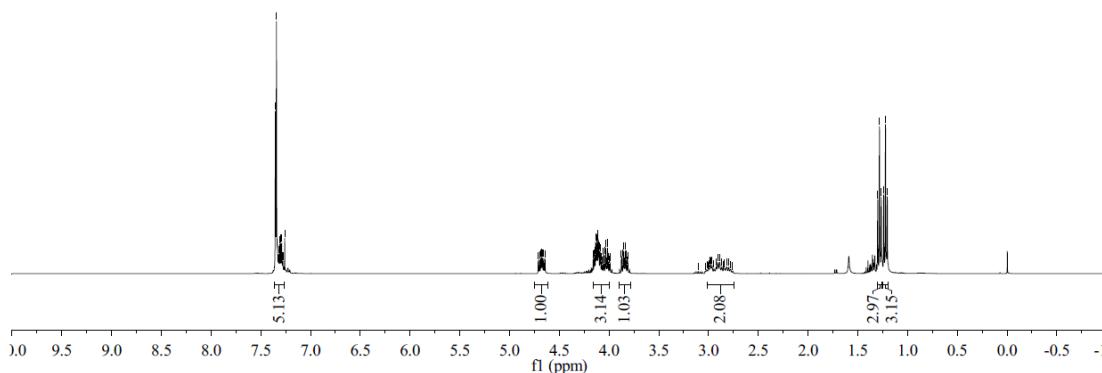
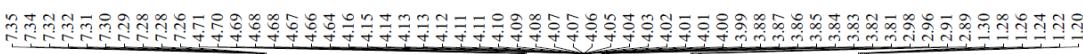
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **8h** in  $\text{CDCl}_3$



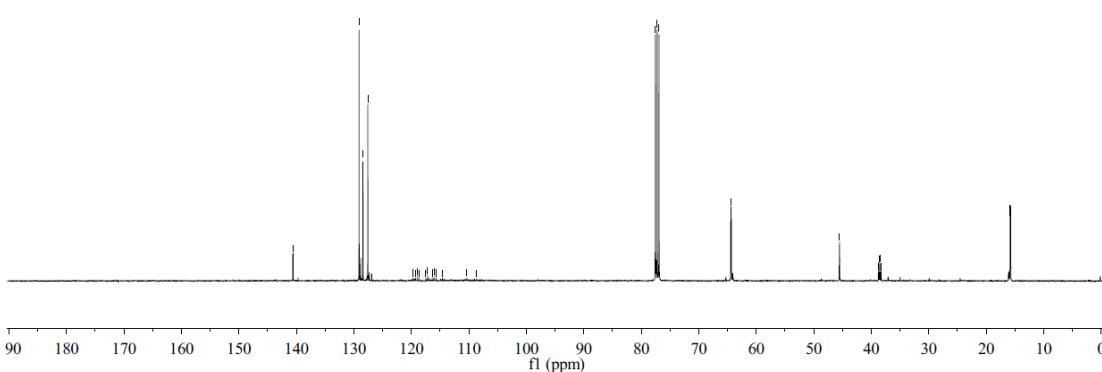
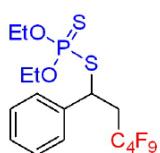
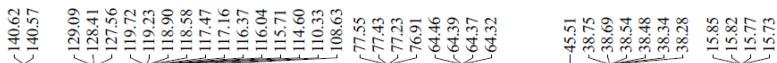
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **8h** in  $\text{CDCl}_3$



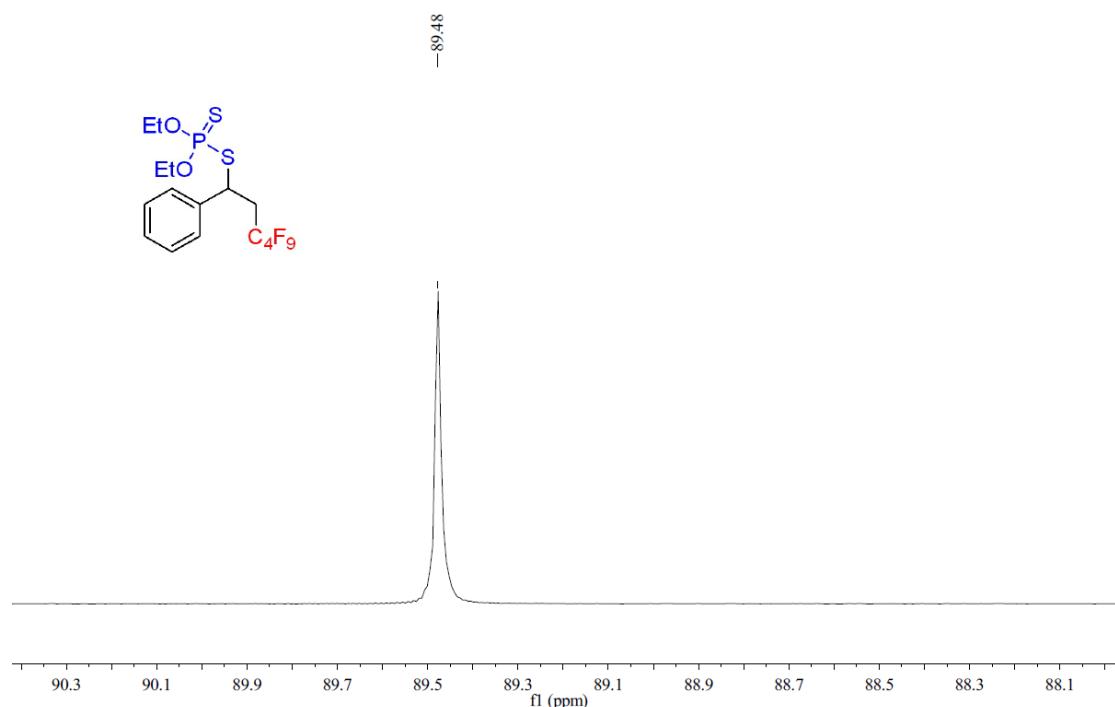
<sup>1</sup>H NMR (400 MHz) Spectrum of **8i** in CDCl<sub>3</sub>



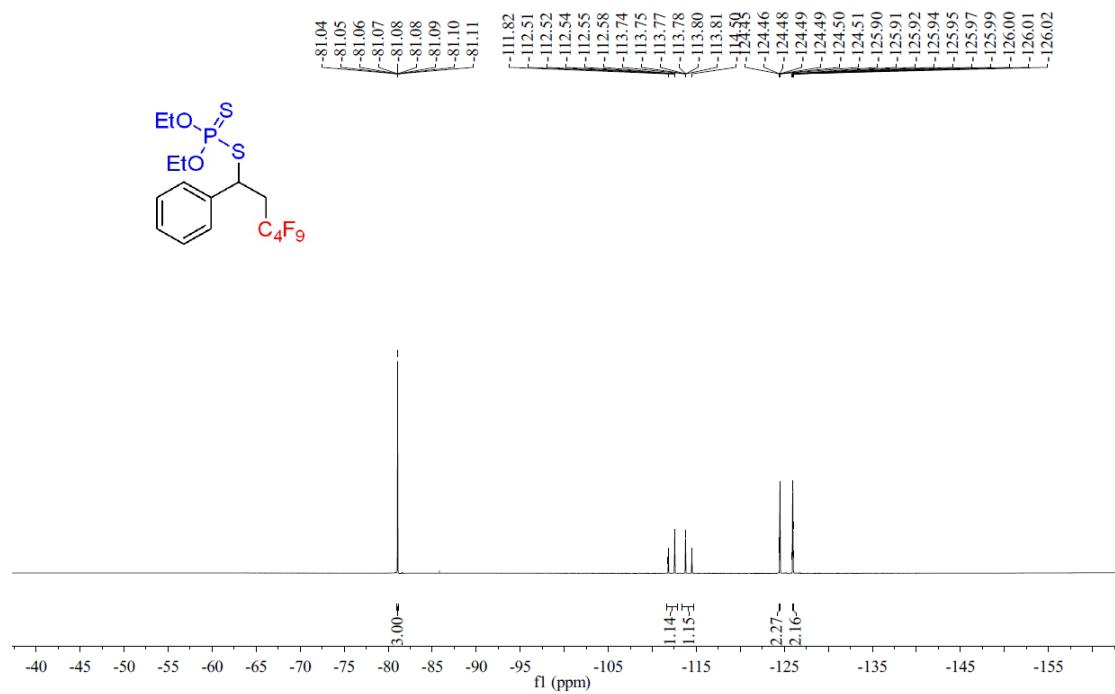
<sup>13</sup>C NMR (151 MHz) Spectrum of **8i** in CDCl<sub>3</sub>



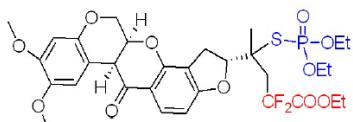
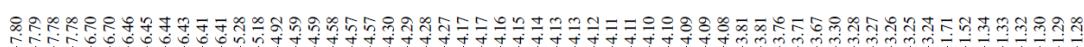
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **8i** in  $\text{CDCl}_3$



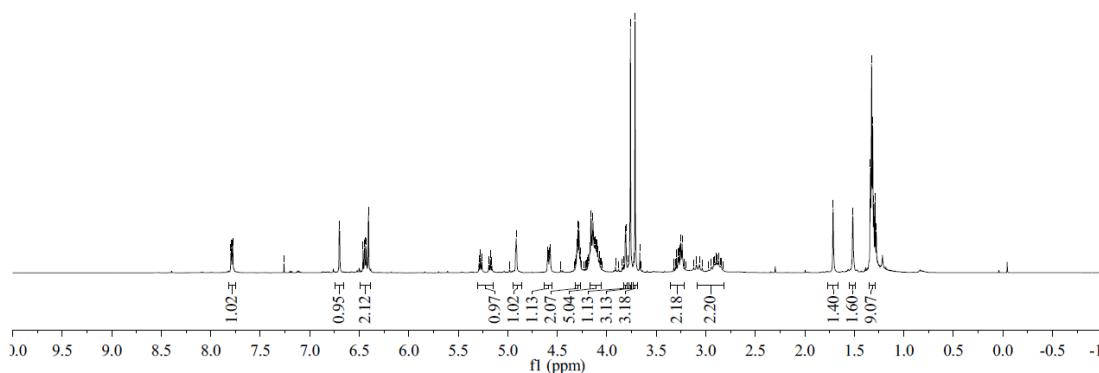
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **8i** in  $\text{CDCl}_3$



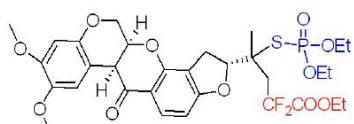
<sup>1</sup>H NMR (400 MHz) Spectrum of **9a** in CDCl<sub>3</sub>



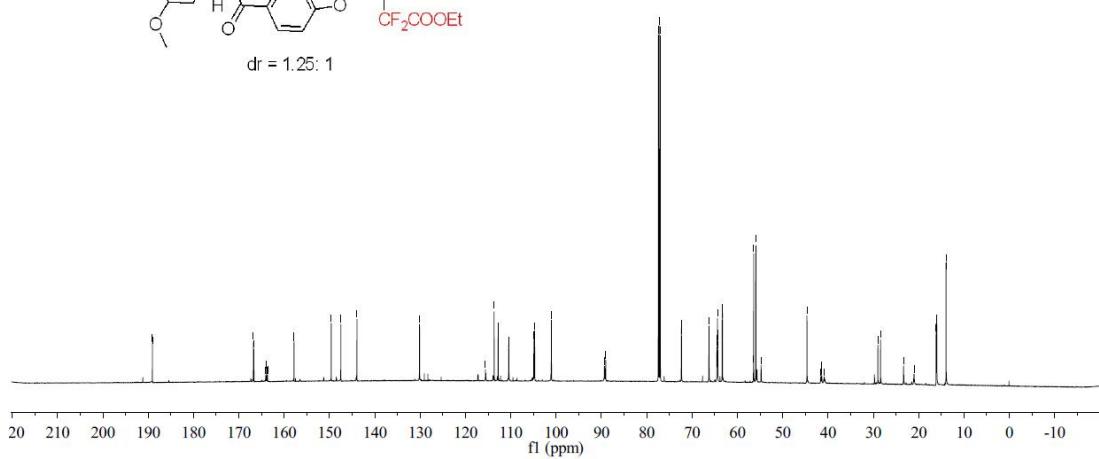
$\text{d}r = 1.25: 1$



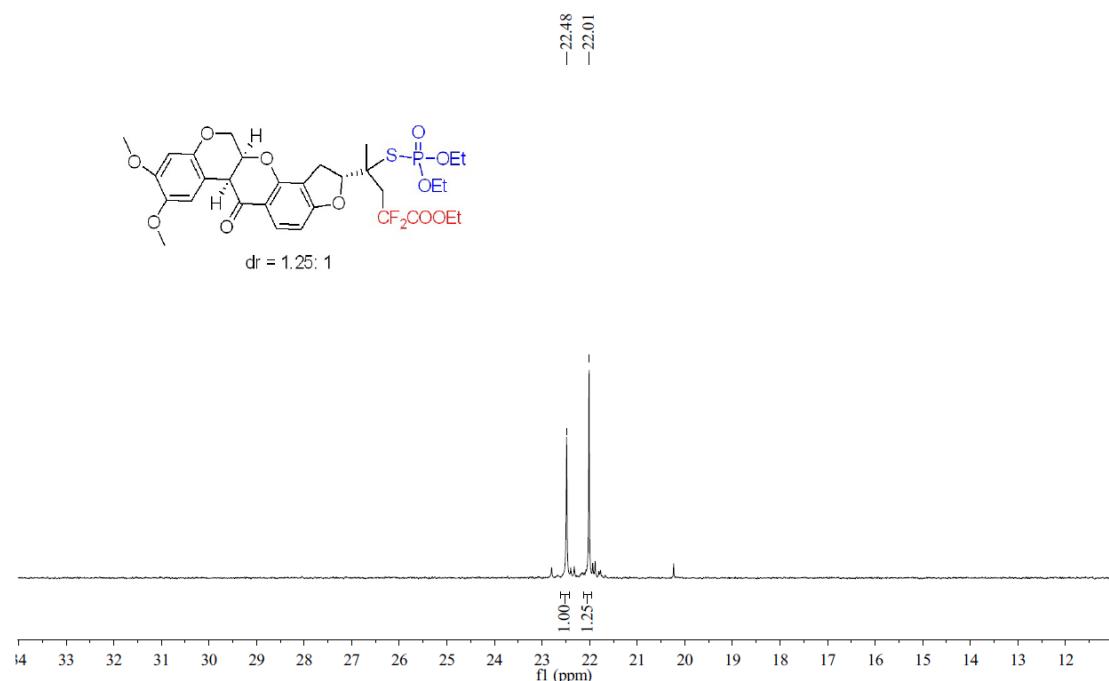
<sup>13</sup>C NMR (151 MHz) Spectrum of **9a** in CDCl<sub>3</sub>



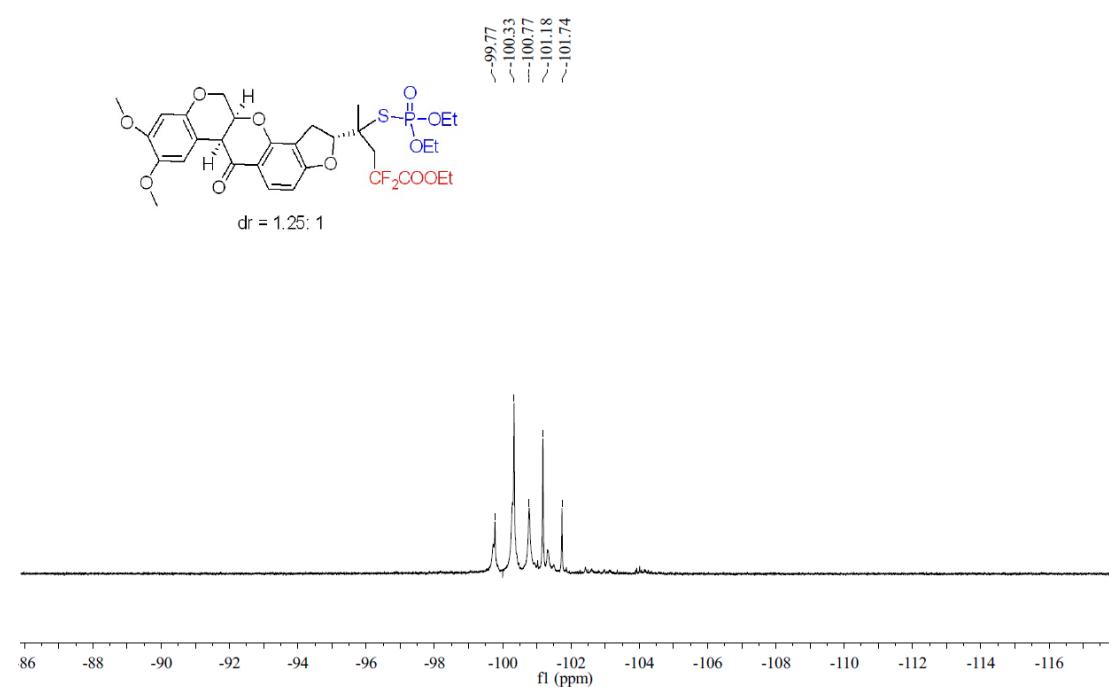
$d_r = 1.25: 1$



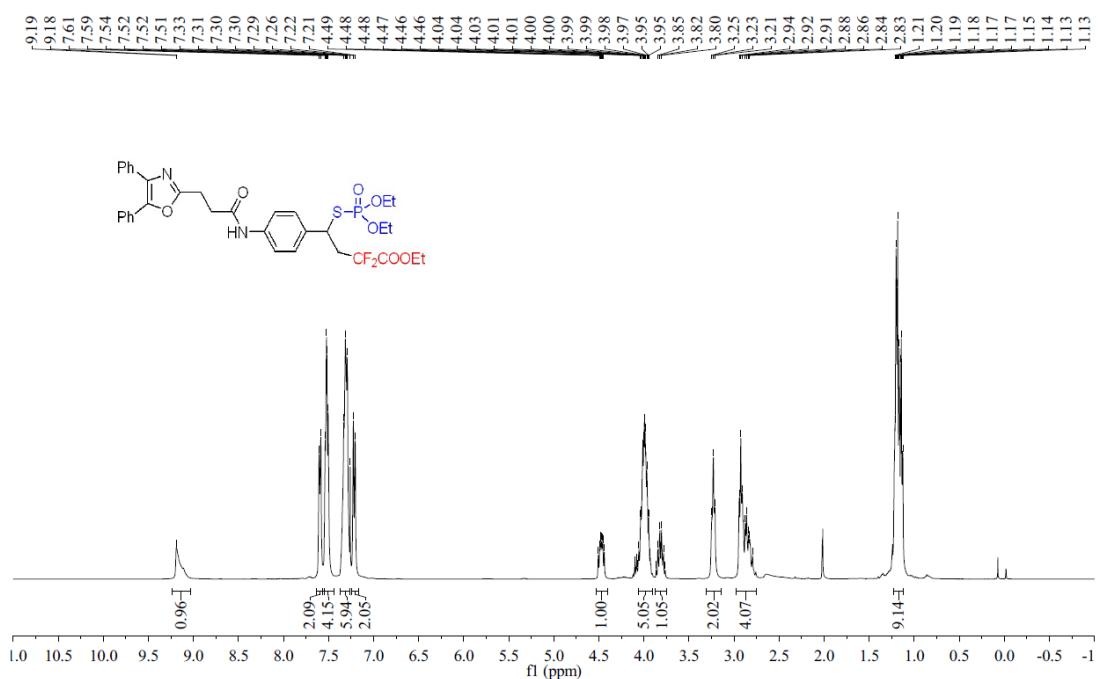
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **9a** in  $\text{CDCl}_3$



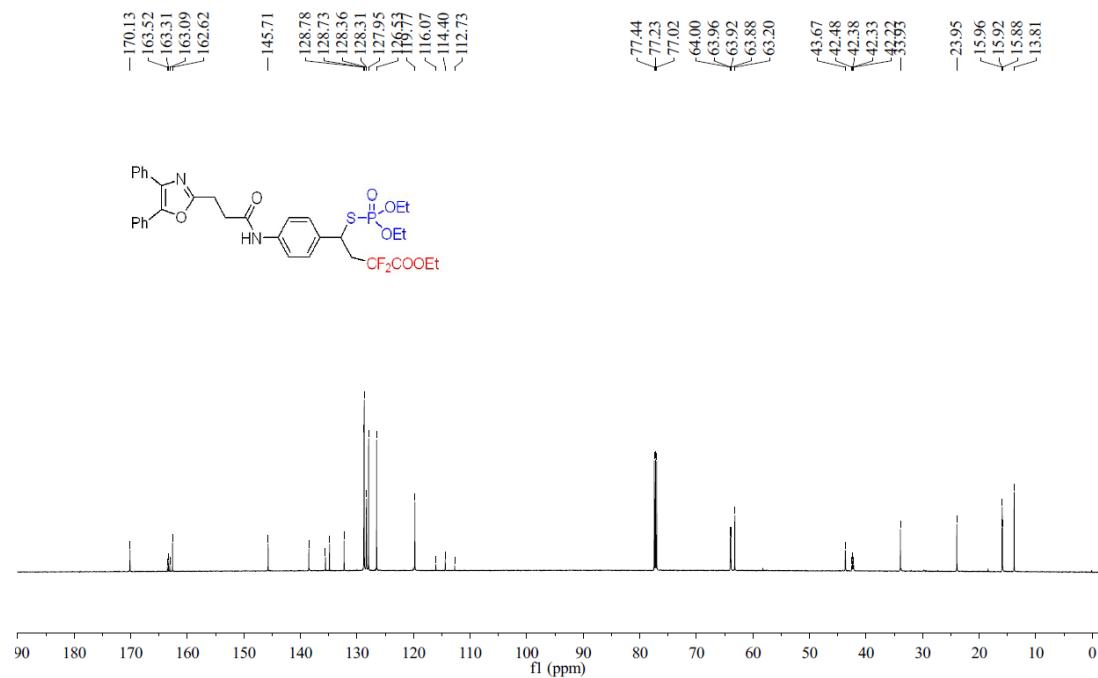
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **9a** in  $\text{CDCl}_3$



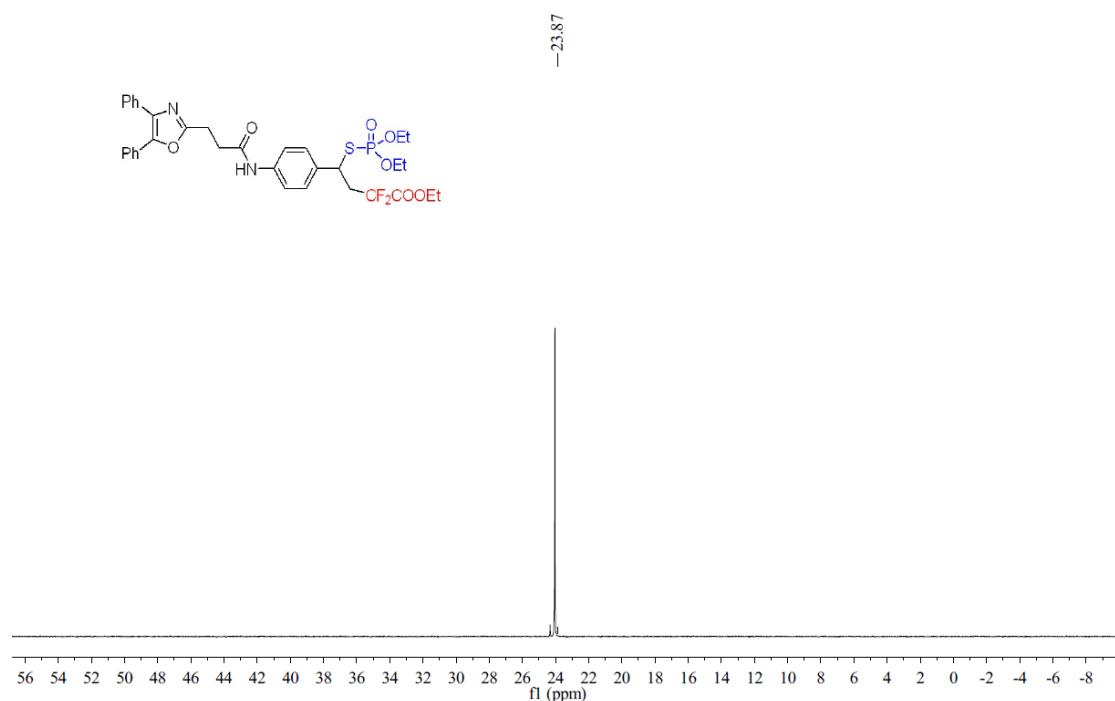
<sup>1</sup>H NMR (400 MHz) Spectrum of **9b** in CDCl<sub>3</sub>



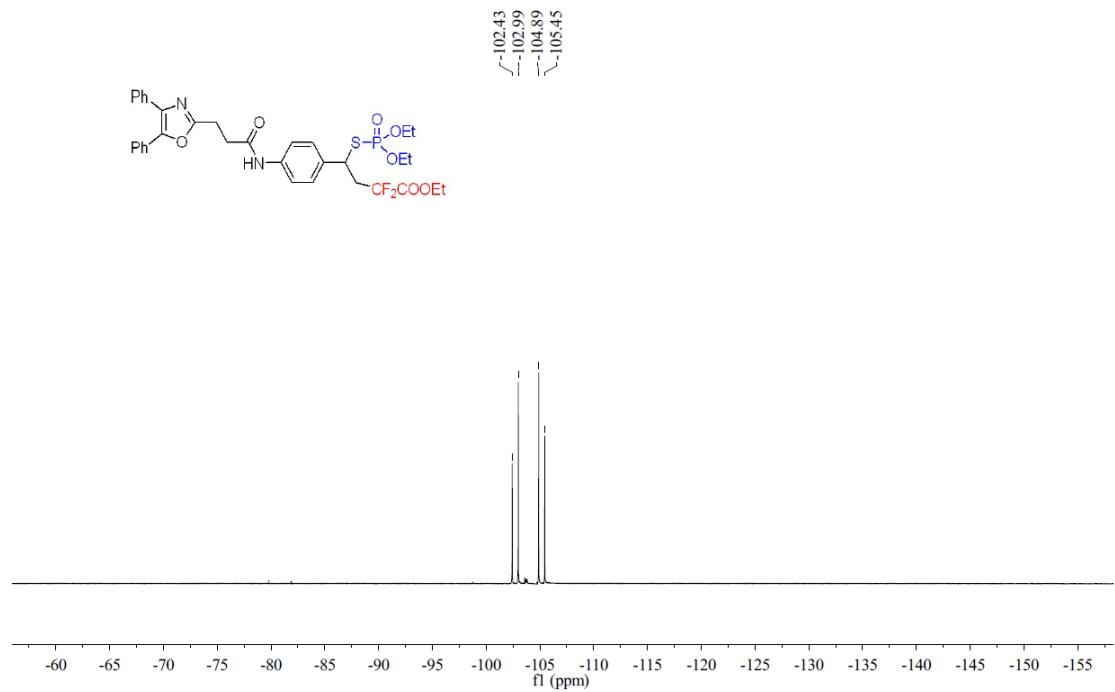
<sup>13</sup>C NMR (151 MHz) Spectrum of **9b** in CDCl<sub>3</sub>



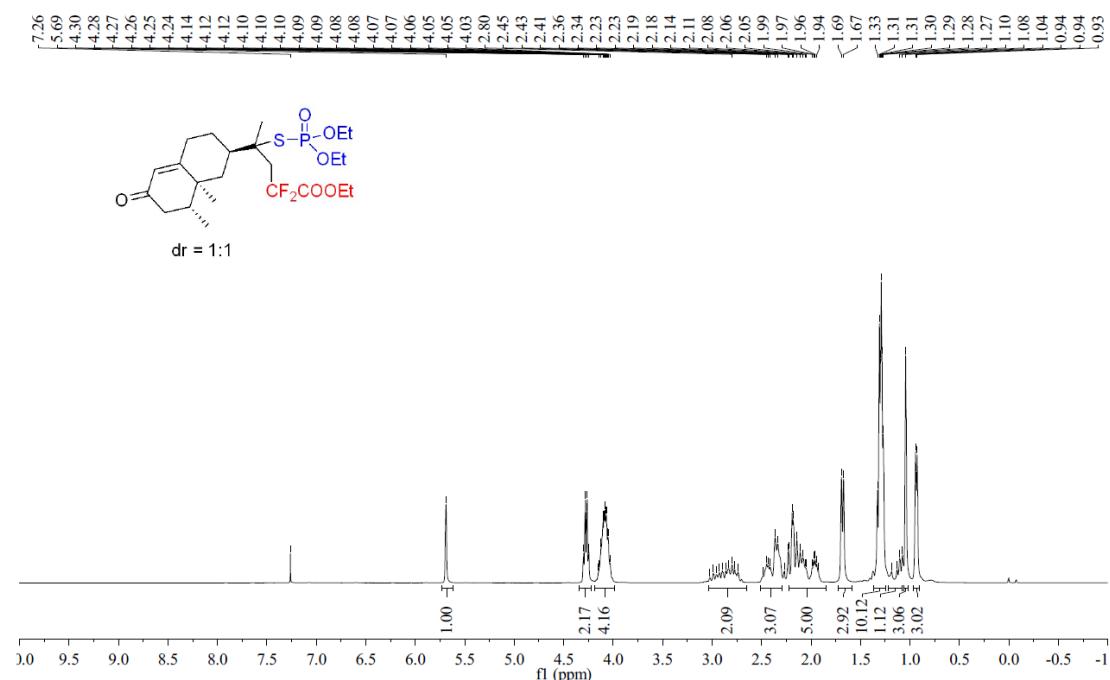
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **9b** in  $\text{CDCl}_3$



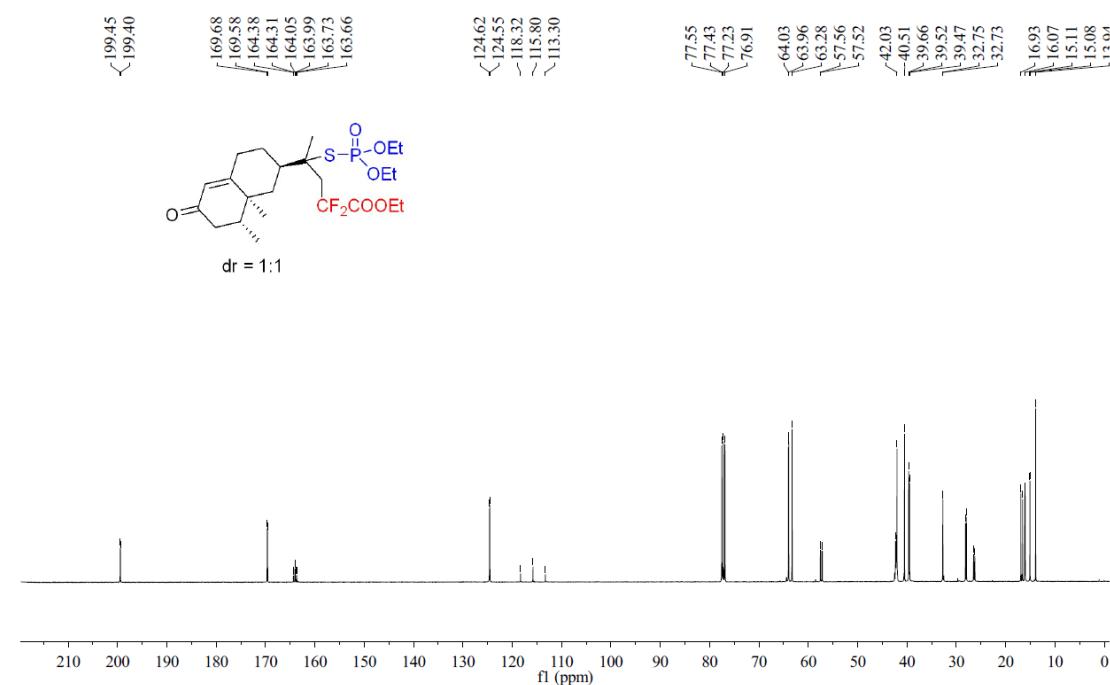
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **9b** in  $\text{CDCl}_3$



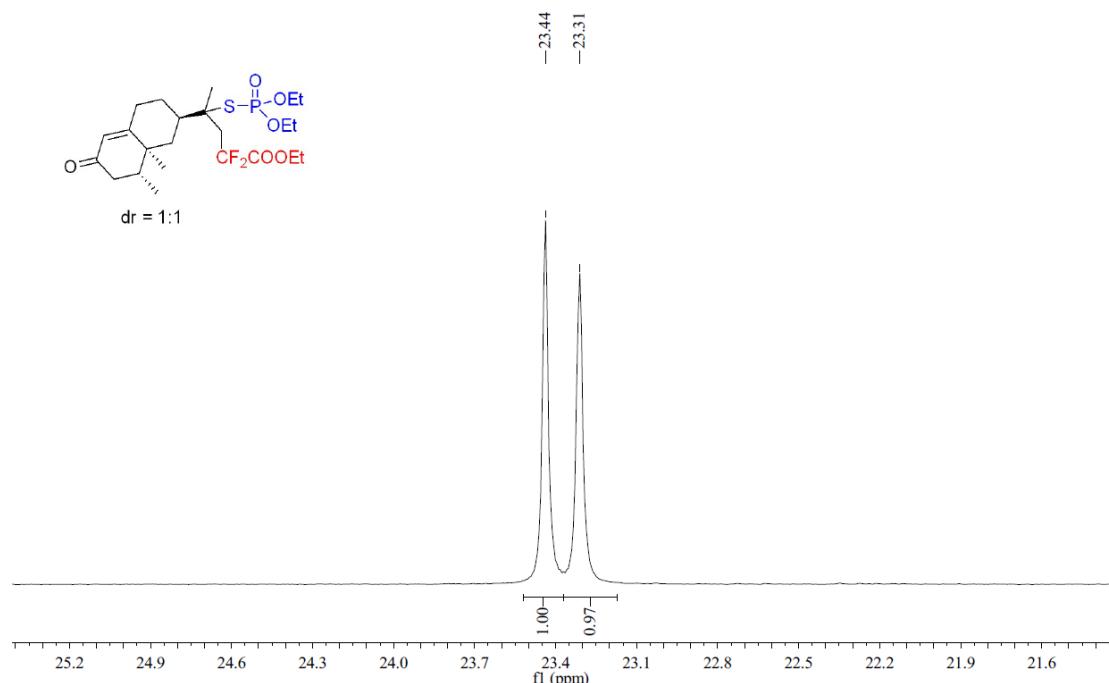
<sup>1</sup>H NMR (400 MHz) Spectrum of **9c** in CDCl<sub>3</sub>



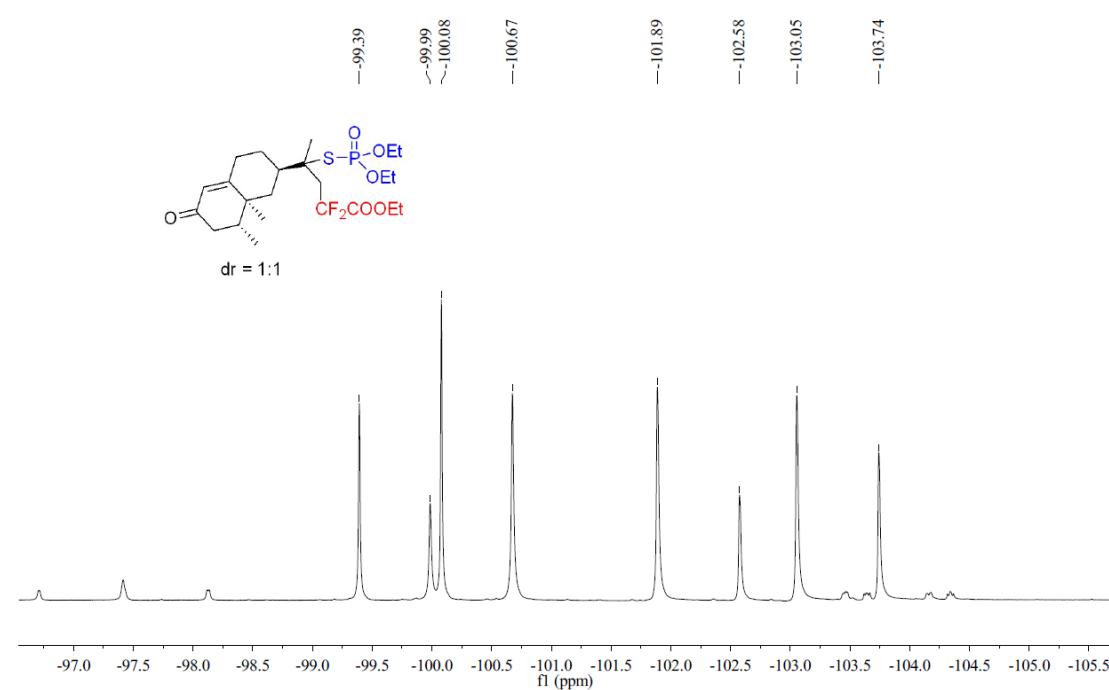
<sup>13</sup>C NMR (151 MHz) Spectrum of **9c** in CDCl<sub>3</sub>



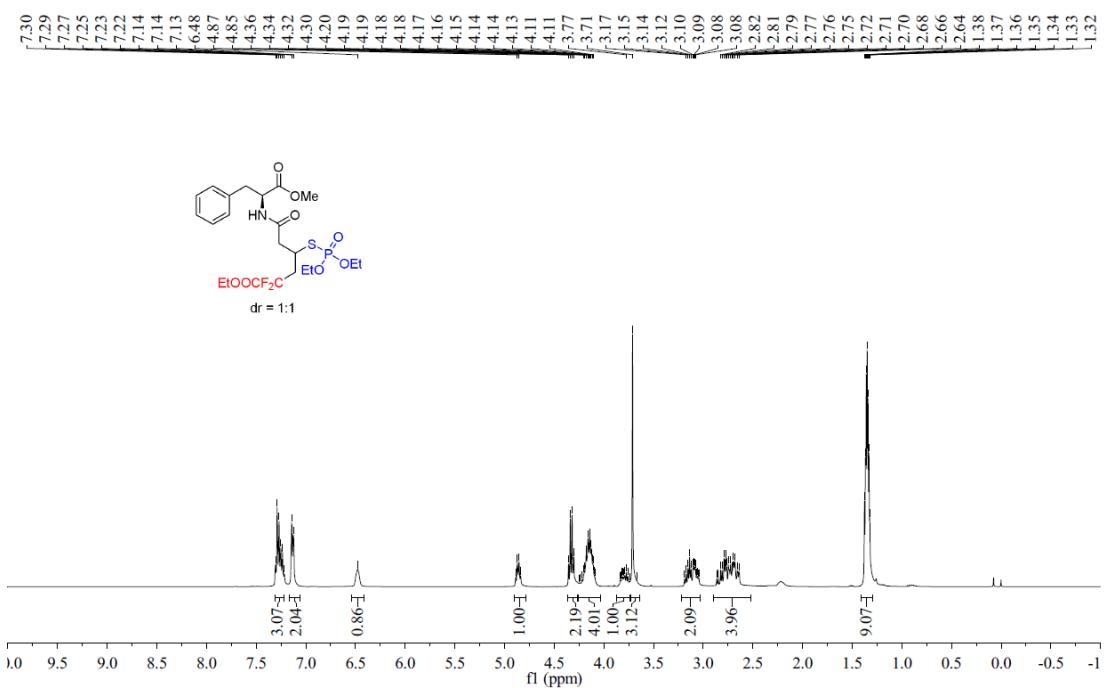
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **9c** in  $\text{CDCl}_3$



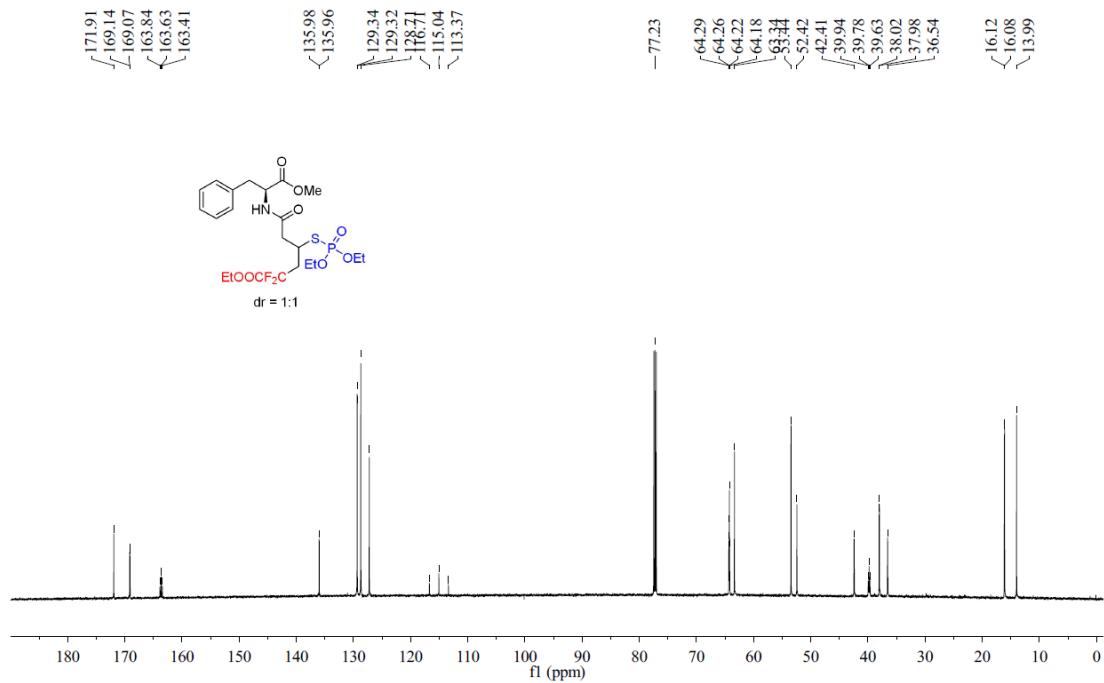
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **9c** in  $\text{CDCl}_3$



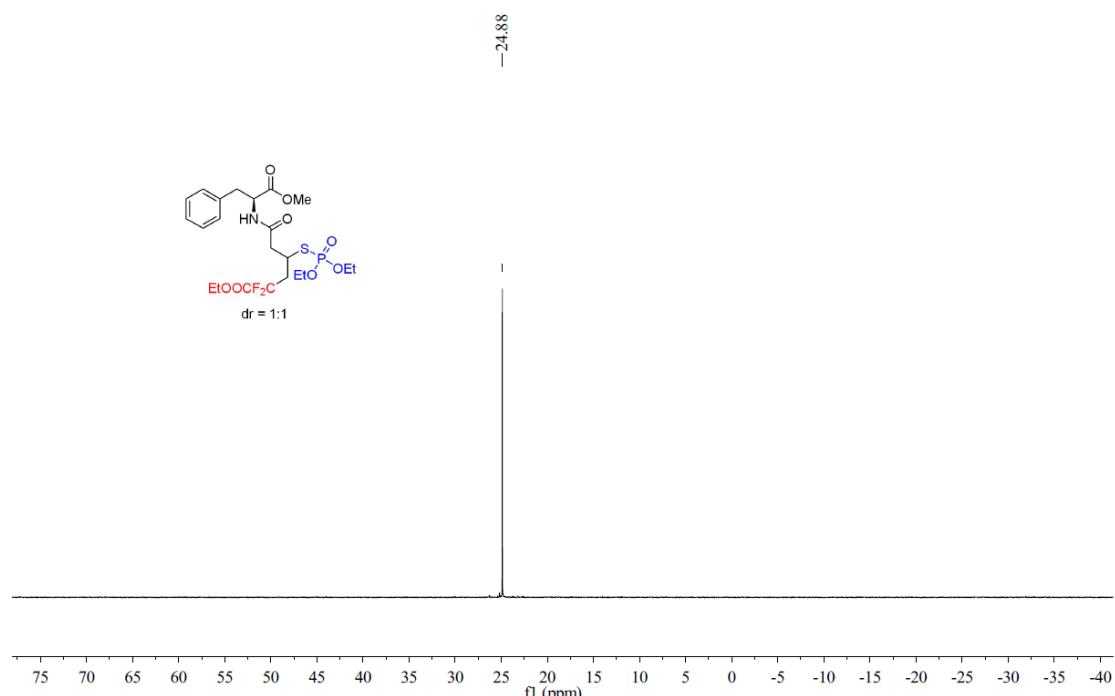
<sup>1</sup>H NMR (400 MHz) Spectrum of **9d** in CDCl<sub>3</sub>



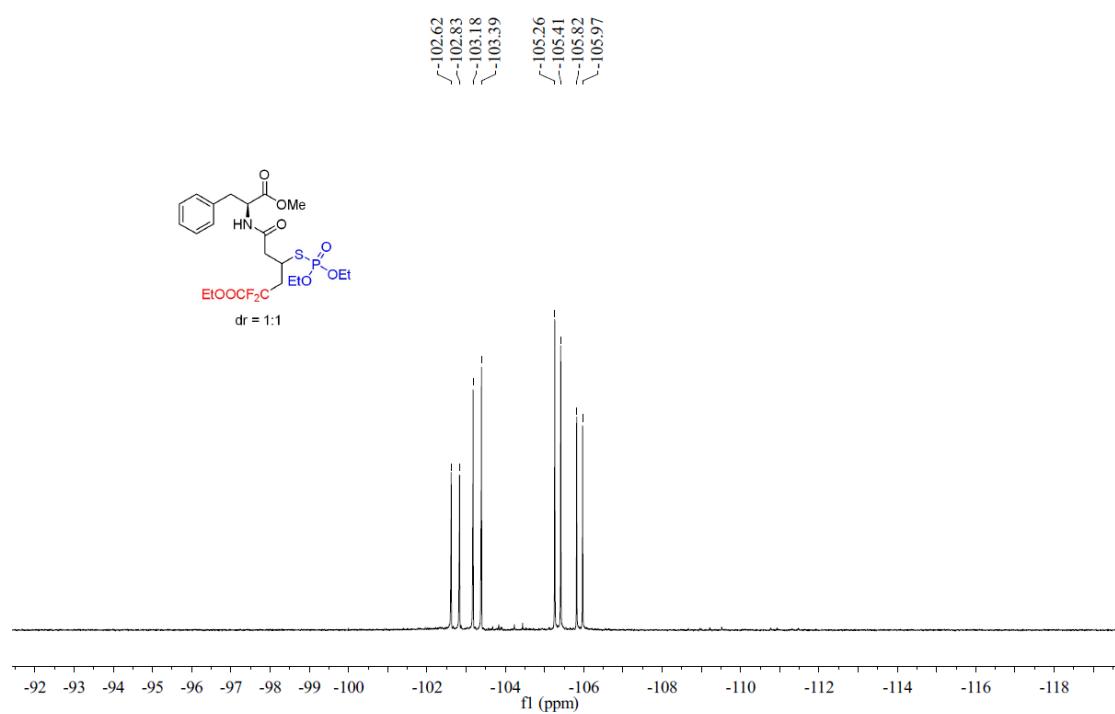
<sup>13</sup>C NMR (151 MHz) Spectrum of **9d** in CDCl<sub>3</sub>



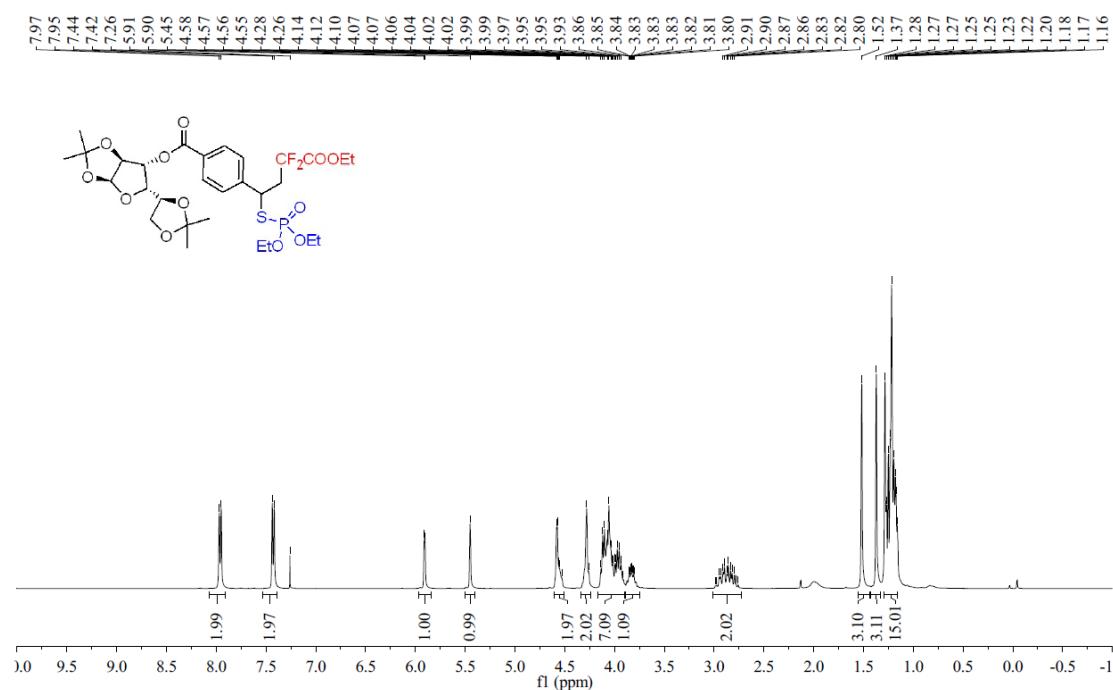
<sup>31</sup>P NMR (243 MHz) Spectrum of **9d** in CDCl<sub>3</sub>



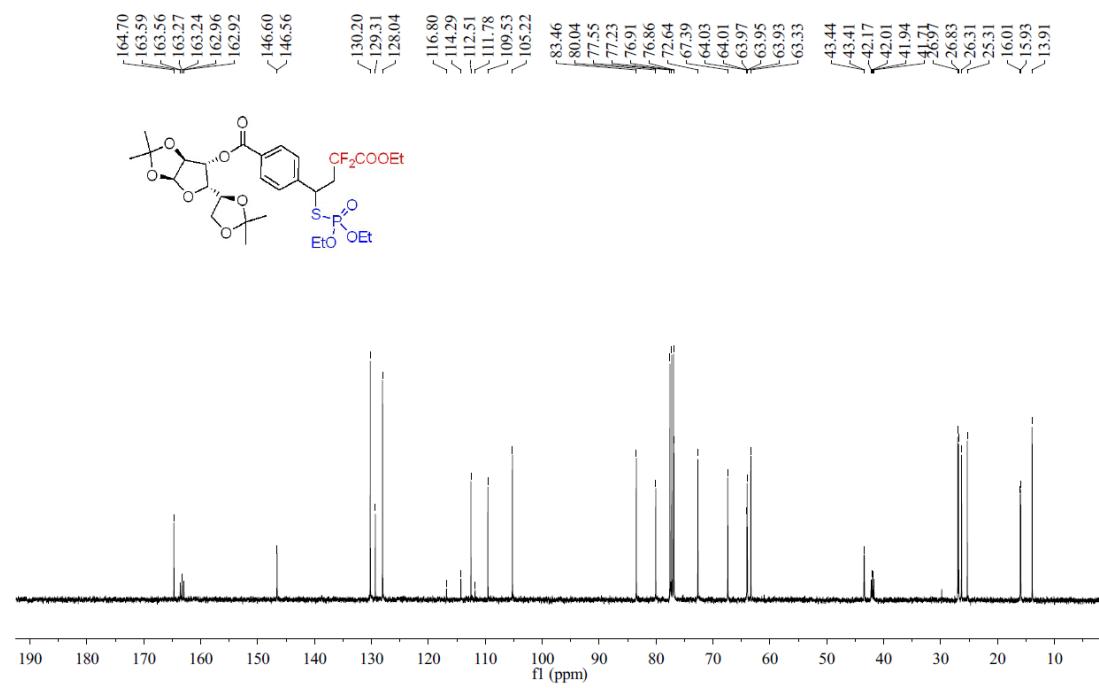
<sup>19</sup>F NMR (471 MHz) Spectrum of **9d** in CDCl<sub>3</sub>



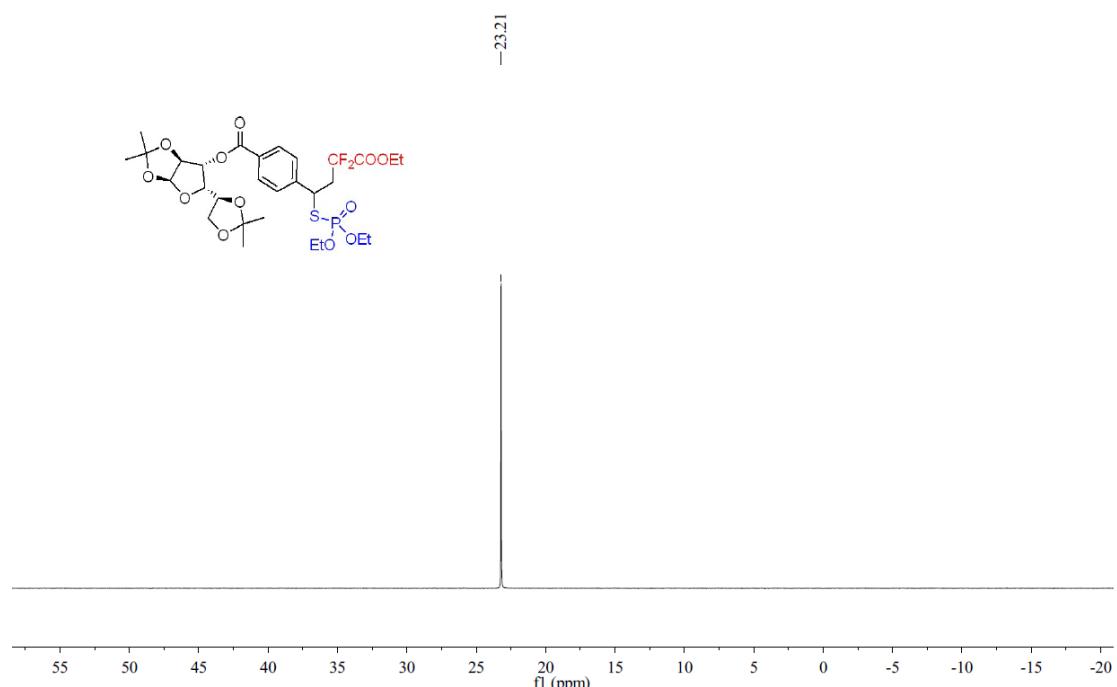
<sup>1</sup>H NMR (400 MHz) Spectrum of **9e** in CDCl<sub>3</sub>



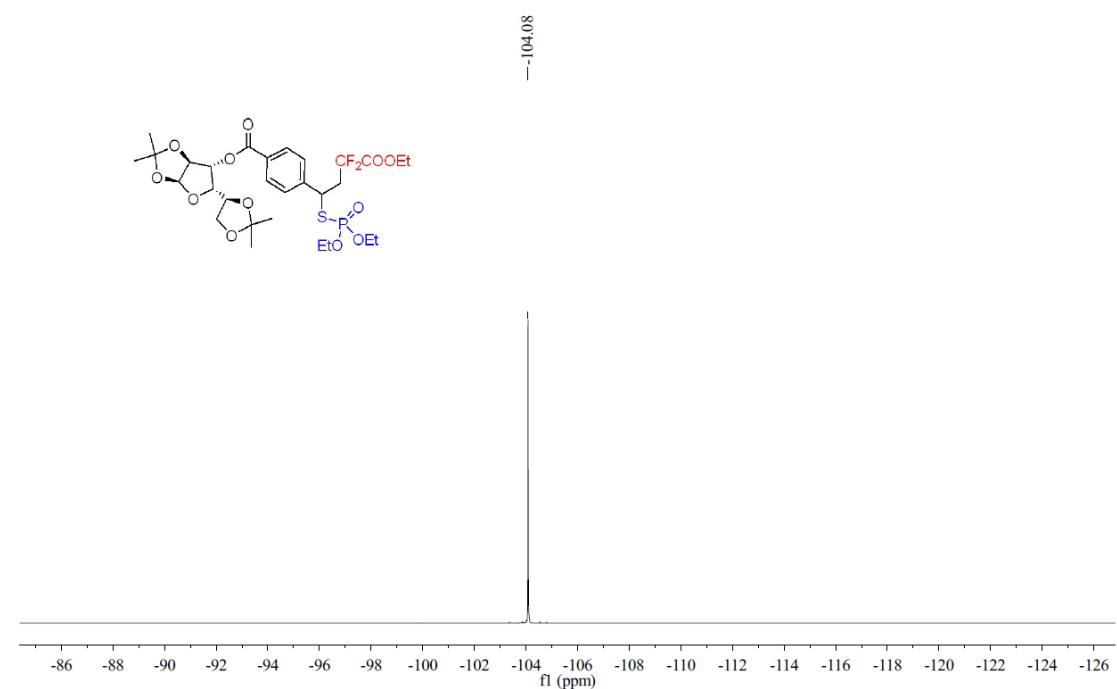
<sup>13</sup>C NMR (151 MHz) Spectrum of **9e** in CDCl<sub>3</sub>



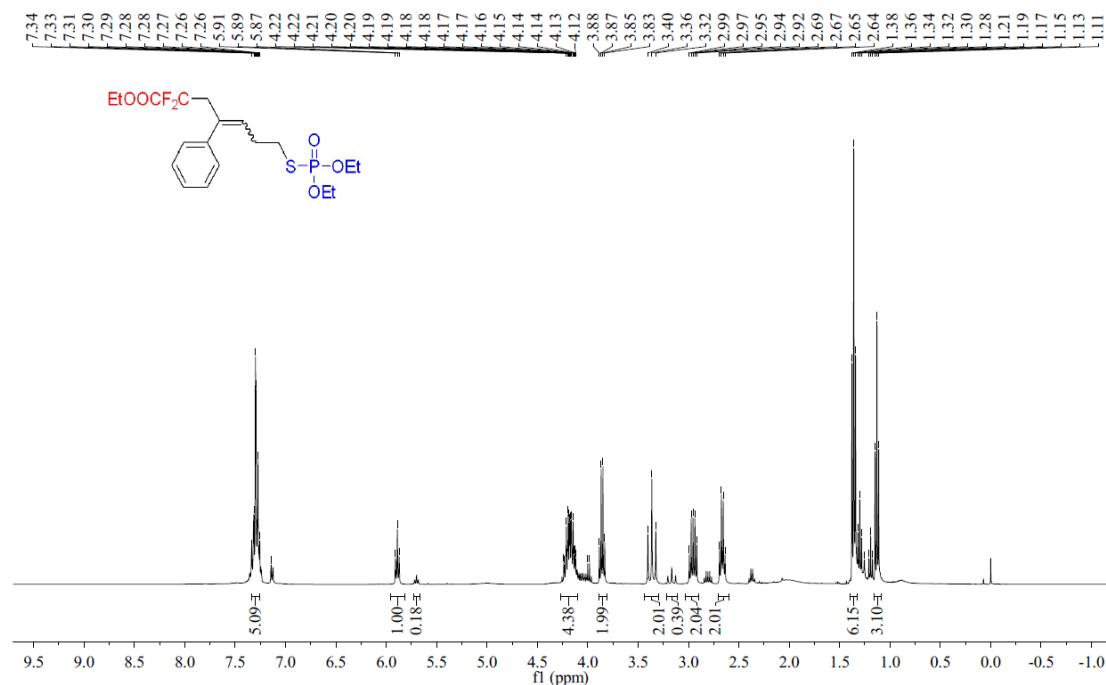
$^{31}\text{P}$  NMR (243 MHz) Spectrum of **9e** in  $\text{CDCl}_3$



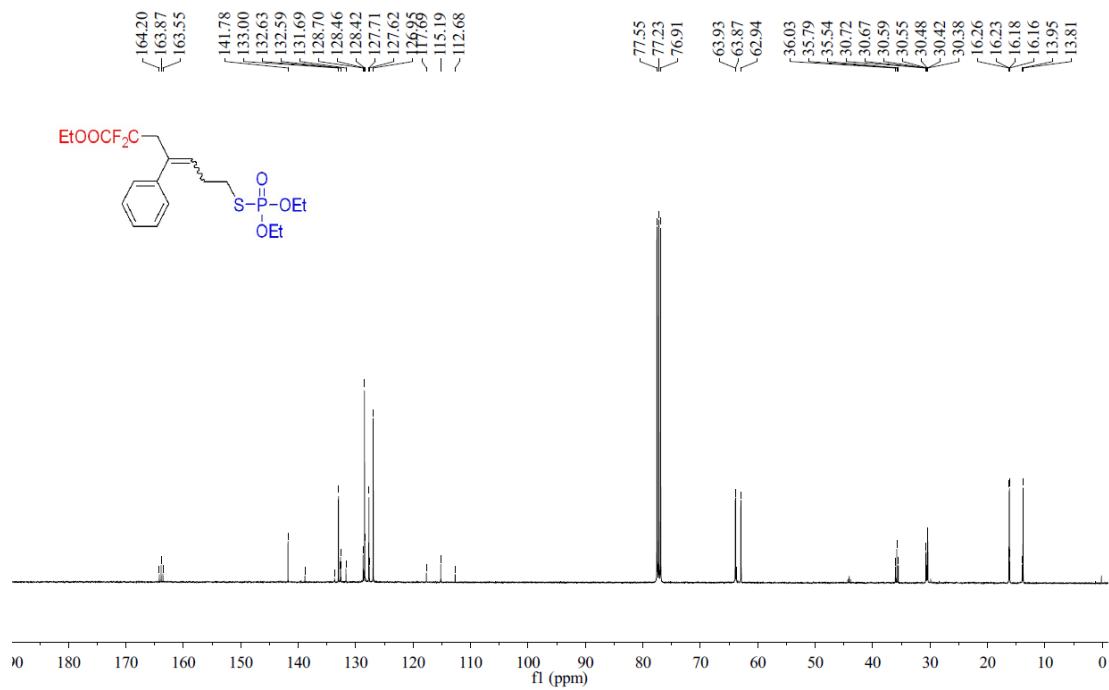
$^{19}\text{F}$  NMR (471 MHz) Spectrum of **9e** in  $\text{CDCl}_3$



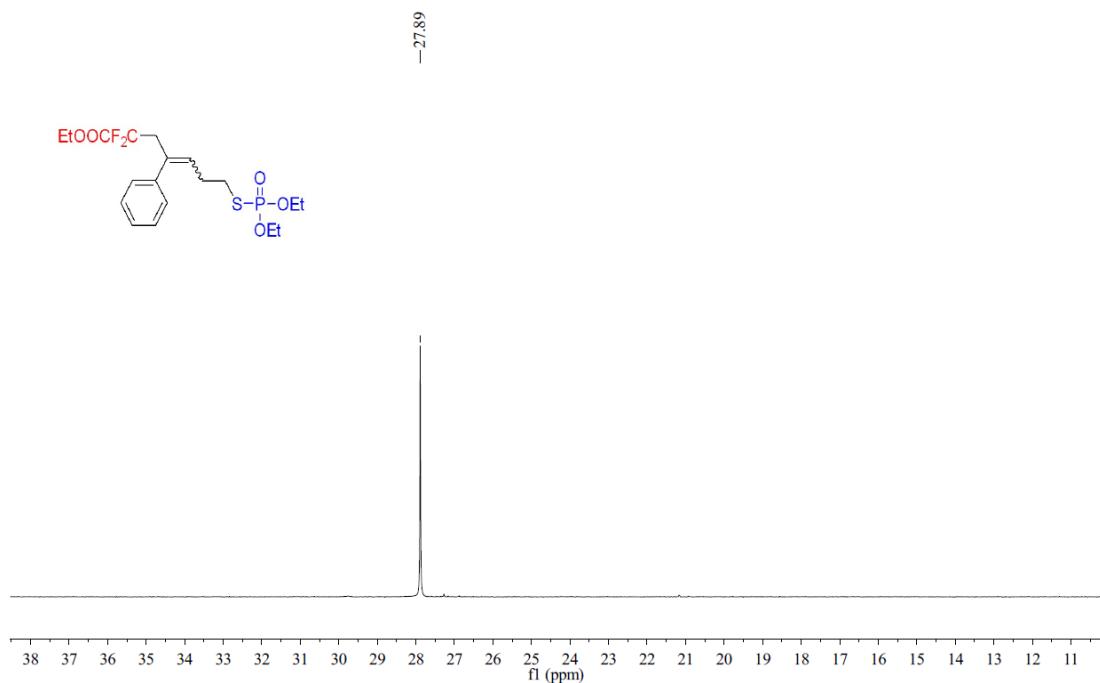
<sup>1</sup>H NMR (400 MHz) Spectrum of **11** in CDCl<sub>3</sub>



<sup>13</sup>C NMR (151 MHz) Spectrum of **11** in CDCl<sub>3</sub>



<sup>31</sup>P NMR (243 MHz) Spectrum of **11** in CDCl<sub>3</sub>



<sup>19</sup>F NMR (471 MHz) Spectrum of **11** in CDCl<sub>3</sub>

