Electronic Supplementary Information

for

Photoredox/copper-catalyzed coupling of terminal alkynes with P(O)SH compounds leading to alkynyl phosphorothioates

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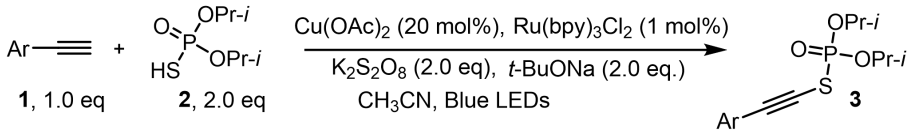
General Information:

^{1}H, ^{13}C and ^{31}P NMR spectra were recorded on a Bruker Av600 spectrometer using tetramethylsilane (TMS) in $CDCl_3$ as the internal standard for ^{1}H, and ^{13}C NMR (^{1}H NMR: TMS at 0.00 ppm, $CHCl_3$ at 7.26 ppm; ^{13}C NMR: $CDCl_3$ at 77.16 ppm) and 85% H_3PO_4 as external standard for ^{31}P NMR. Data are represented as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constants in Hertz (Hz), integration. The products were purified by Column chromatography on silica gel 300 − 400 mesh. All products were firstly examined by Bruker AmaZon SL ESI-IT-MS (Bruker Daltonics Inc., Germany) in positive ion mode, then further characterized by HRMS (ESI-qTOF MS, Bruker micrOTOF-Q II) in positive ion mode too.

1. Synthesis of substrates.

Experimental procedure for synthesis of *O,O-diisopropyl S-(phenylethynyl) phosphorothioate*



To an oven-dried vial were added $Ru(bpy)_3Cl_2$ (1 mol%), $Cu(OAc)_2$ (3.9 mg, 0.02 mmol, 0.2 equiv), $K_2S_2O_8$ (54mg, 0.2 mmol 2.0 equiv) and *t*-BuONa (19.2mg, 0.2 mmol, 0.2equiv). Freshly distilled CH_3CN (2.0 mL), **1** (10.2 mg, 0.1 mmol, 1.0 equiv) and **2** (39.6 mg, 0.2 mmol, 2.0 equiv) were sequentially added to the system at room temperature. The resulting mixture was irradiated with 30 W blue LEDs strip for 24 h. After the removal of solvents under reduced pressure, the crude product was purified by column chromatography on silica gel with ethyl acetate/petroleum ether [1:3 (v/v)] as the eluent to give the pure product *O,O-diisopropyl S-(phenylethynyl) phosphorothioate* (**3**) (20.9 mg, 70%).

EPR experiments

(T=300 K)

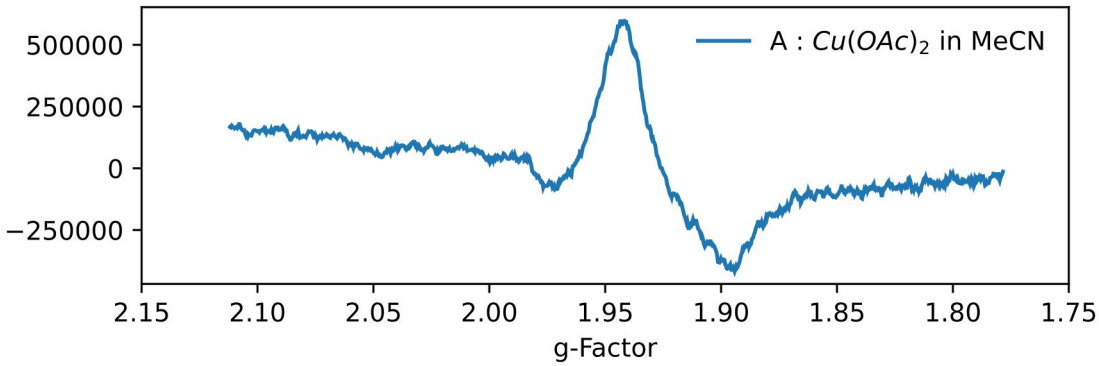


Fig 1 A: $Cu(OAc)_2$ (20 mol%) in MeCN (2 mL) (g=1.926)

(T=300 K)

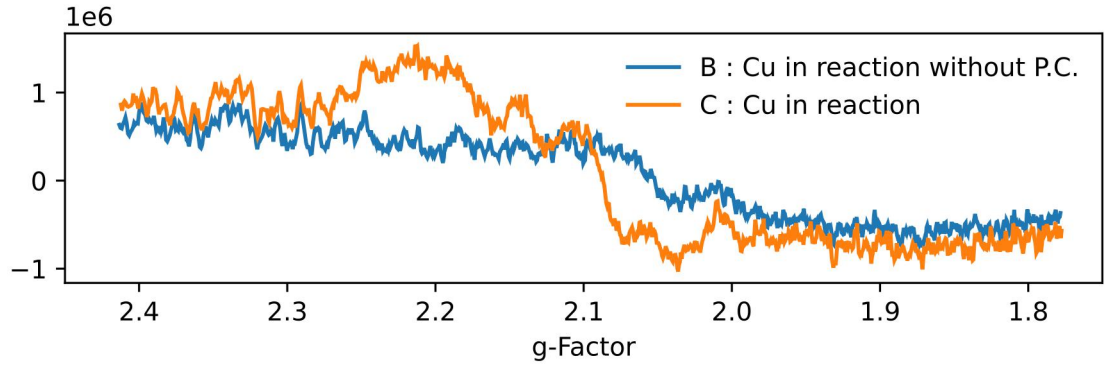
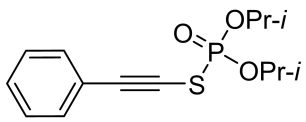


Fig 2 B: **1** (0.1 mmol), **2** (0.2 mmol), $Cu(OAc)_2$ (20 mol%), $K_2S_2O_8$ (0.2 mmol) and *t*-BuONa (0.2 mmol) in MeCN (2 mL) at room temperature for 16 h. C: **1** (0.1 mmol), **2** (0.2 mmol), $Ru(bpy)_3Cl_2$ (1 mol%), $Cu(OAc)_2$ (20 mol%), $K_2S_2O_8$ (0.2 mmol) and *t*-BuONa (0.2 mmol) in MeCN (2 mL) at room temperature under irradiation by blue LEDs (30 W) for 16 h (g = 2.087).

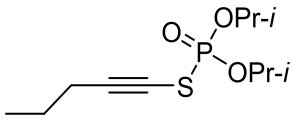
Spectral data

_O,O_-diisopropyl _S_-(phenylethynyl) phosphorothioate (3)



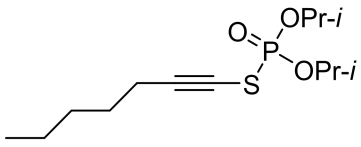
Yield: 20.9 mg, 70%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.42-7.41 (m, 2H), 7.35-7.29 (m, 3H), 4.97-4.91 (m, 2H), 1.45 (t, J = 5.64 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 131.9 (d, J = 3.1 Hz), 128.9 (s), 128.5 (s), 122.7 (d, J = 4.0 Hz), 92.2 (d, J = 8.7 Hz), 74.7 (d, J = 6.2 Hz), 70.6 (d, J = 11.8 Hz), 24.0 (d, J = 4.2 Hz), 23.7 (d, J = 6.3 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.4 (s). HRMS calcd for $C_{14}H_{19}NaO_3PS^+$ $[M+Na]^+$, 321.0685; found, 321.0681.

_O,O_-diisopropyl _S_-(pent-1-yn-1-yl) phosphorothioate (4)



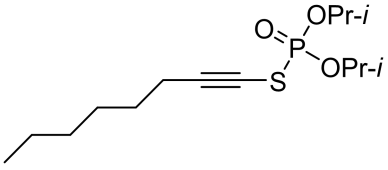
Yield: 15.8 mg, 60%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 4.90-4.84 (m, 2H), 2.27-2.24 (m, 2H), 1.55-1.52 (m, 2H), 1.41 (dd, J_1 = 2.16 Hz, J_2 = 6.18 Hz, 12H). 0.98 (t, J = 7.38 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 94.0 (d, J = 8.7 Hz), 74.3 (d, J = 5.8 Hz), 59.6 (d, J = 11.3 Hz), 24.0 (d, J = 4.3 Hz), 23.6 (d, J = 5.7 Hz). 22.04 (s), 22.01 (d, J = 2.4 Hz), 13.6 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 17.2 (s). HRMS calcd for $C_{11}H_{22}O_3PS^+$ $[M+H]^+$, 265.1022; found, 265.1028.

_S_-(hept-1-yn-1-yl) _O,O_-diisopropyl phosphorothioate (5)



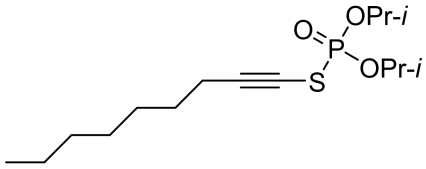
Yield: 18.7 mg, 64%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 4.88-4.85 (m, 2H), 2.29-2.25 (m, 2H), 1.52-1.48 (m, 2H), 1.41 (dd, J_1 = 2.13 Hz, J_2 = 6.15 Hz, 12H). 1.39-1.33 (m, 2H), 1.32-1.28 (m, 2H), 0.89 (t, J = 7.17 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 94.2 (d, J = 8.7 Hz), 74.3 (d, J = 6.1 Hz), 59.4 (d, J = 11.5 Hz), 31.1 (s), 28.2 (d, J = 2.1 Hz), 24.0 (d, J = 4.3 Hz), 23.6 (d, J = 6.3 Hz). 22.3 (s), 20.0 (d, J = 3.1 Hz), 14.1 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 17.2 (s). HRMS calcd for $C_{13}H_{26}O_3PS^+$ $[M+H]^+$, 293.1335; found, 293.1333.

_O,O_-diisopropyl _S_-(oct-1-yn-1-yl) phosphorothioate (6)



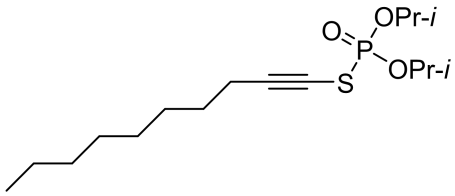
Yield: 19.6 mg, 64%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 4.88-4.84 (m, 2H), 2.28-2.25 (m, 2H), 1.50-1.47 (m, 2H), 1.41 (dd, J_1 = 2.37 Hz, J_2 = 6.21 Hz, 12H). 1.39-1.34 (m, 2H), 1.31-1.23 (m, 4H), 0.88 (t, J = 7.08 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 94.2 (d, J = 8.0 Hz), 74.2 (d, J = 5.9 Hz), 59.4 (d, J = 11.3 Hz), 31.4 (s), 28.6 (s), 28.5 (d, J = 2.3 Hz), 24.0 (d, J = 3.6 Hz), 23.6 (d, J = 5.8 Hz). 22.7 (s), 20.1 (d, J = 2.4 Hz), 14.2 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 17.2 (s). HRMS calcd for $C_{14}H_{27}NaO_3PS^+$ $[M+Na]^+$, 329.1311; found, 329.1304.

***O,O*-diisopropyl *S*-(non-1-yn-1-yl) phosphorothioate (7)**



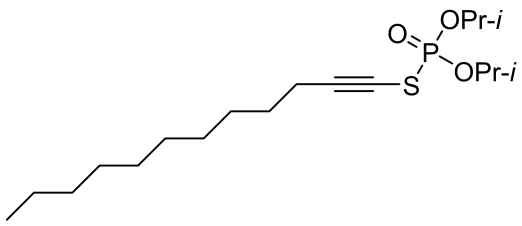
Yield: 18.9 mg, 59%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 4.89-4.84 (m, 2H), 2.28-2.25 (m, 2H), 1.51-1.47 (m, 2H), 1.41 (dd, J_1 = 2.59 Hz, J_2 = 6.18 Hz, 12H). 1.37-1.34 (m, 2H), 1.30-1.24 (m, 6H), 0.87 (t, J = 6.99 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 94.2 (d, J = 8.0 Hz), 74.2 (d, J = 6.2 Hz), 59.4 (d, J = 11.3 Hz), 31.8 (s), 28.9 (s), 28.8 (s), 28.5 (d, J = 2.5 Hz), 24.0 (d, J = 4.3 Hz), 23.6 (d, J = 5.9 Hz). 22.7 (s), 20.1 (d, J = 3.0 Hz), 14.2 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 17.2 (s). HRMS calcd for $C_{15}H_{29}NaO_3PS^+$ $[M+Na]^+$, 343.1467; found, 343.1459.

***S*-(dec-1-yn-1-yl) *O,O*-diisopropyl phosphorothioate (8)**



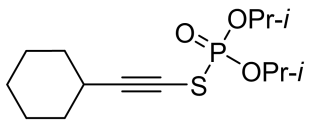
Yield: 21.1 mg, 63%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 4.88-4.83 (m, 2H), 2.27-2.24 (m, 2H), 1.51-1.46 (m, 2H), 1.40 (dd, J_1 = 2.40 Hz, J_2 = 6.18 Hz, 12H). 1.38-1.33 (m, 2H), 1.30-1.25 (m, 8H), 0.86 (t, J = 6.99 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 94.1 (d, J = 8.0 Hz), 74.2 (d, J = 6.1 Hz), 59.4 (d, J = 11.5 Hz), 31.9 (s), 29.3 (s), 29.2 (s), 28.9 (s), 28.5 (d, J = 2.0 Hz), 24.0 (d, J = 4.2 Hz), 23.6 (d, J = 6.2 Hz). 22.7 (s), 20.0 (d, J = 3.1 Hz), 14.2 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 17.0 (s). HRMS calcd for $C_{16}H_{32}O_3PS^+$ $[M+H]^+$, 335.1804; found, 335.1809.

***S*-(dodec-1-yn-1-yl) *O,O*-diisopropyl phosphorothioate (9)**



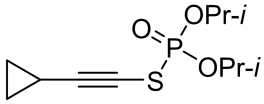
Yield: 24.2 mg, 67%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 4.89-4.83 (m, 2H), 2.28-2.24 (m, 2H), 1.50-1.46 (m, 2H), 1.41 (dd, J_1 = 2.58 Hz, J_2 = 6.18 Hz, 12H). 1.38-1.33 (m, 2H), 1.30-1.25 (m, 12H), 0.87 (t, J = 7.05 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 94.2 (d, J = 8.2 Hz), 74.2 (d, J = 5.6 Hz), 59.4 (d, J = 11.8 Hz), 32.0 (s), 29.7 (s), 29.6 (s), 29.4 (s), 29.2 (s), 28.9 (s), 28.5 (d, J = 2.0 Hz), 24.0 (d, J = 3.8 Hz), 23.6 (d, J = 6.2 Hz). 22.8 (s), 20.0 (d, J = 3.1 Hz), 14.2 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 17.2 (s). HRMS calcd for $C_{18}H_{35}O_3PS^+$ $[M+H]^+$, 363.2117; found, 363.2114.

***S*-(cyclohexylethynyl) *O,O*-diisopropyl phosphorothioate (10)**



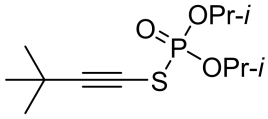
Yield: 19.5 mg, 64%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 4.90-4.84 (m, 2H), 2.48-2.45 (m, 1H), 1.77-1.75 (m, 2H), 1.71-1.66 (m, 2H), 1.52-1.46 (m, 1H), 1.42 (d, J = 6.18 Hz, 12H), 1.39-1.34 (m, 1H), 1.33-1.28 (m, 4H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 97.8 (d, J = 8.3 Hz), 74.2 (d, J = 5.8 Hz), 59.6 (d, J = 11.8 Hz), 32.4 (s), 30.3 (s), 25.9 (s), 24.8 (s), 24.0 (d, J = 4.0 Hz), 23.7 (d, J = 5.7 Hz). ^{1}P NMR (242 MHz, $CDCl_3$) δ (ppm) 17.1 (s). HRMS calcd for $C_{14}H_{25}NaO_3PS^+$ $[M+Na]^+$, 327.1154; found, 327.1153.

***S*-(cyclopropylethynyl) *O,O*-diisopropyl phosphorothioate (11)**



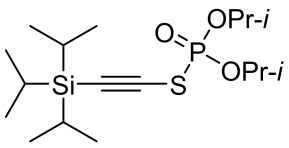
Yield: 15.7 mg, 60%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 4.89-4.82 (m, 2H), 1.42 (dd, J_1 = 4.80 Hz, J_2 = 5.88 Hz, 12H), 1.33-1.29 (m, 1H), 0.81-0.78 (m, 2H), 0.72-0.69 (m, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 97.5 (d, J = 8.5 Hz), 74.3 (d, J = 6.0 Hz), 55.0 (d, J = 11.6 Hz), 24.0 (d, J = 4.1 Hz), 23.6 (d, J = 5.8 Hz). 8.7 (d, J = 2.9 Hz), 0.8 (d, J = 3.3 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 17.3 (s). HRMS calcd for $C_{11}H_{19}NaO_3PS^+$ $[M+Na]^+$, 285.0685; found, 285.0683.

***S*-(3,3-dimethylbut-1-yn-1-yl) *O,O*-diisopropyl phosphorothioate (12)**



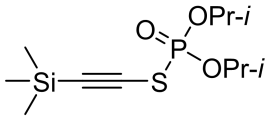
Yield: 21.1 mg, 76%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 4.88-4.82 (m, 2H), 1.40 (d, J = 6.24 Hz, 12H), 1.20 (s, 9H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 101.5 (d, J = 8.5 Hz), 74.1 (d, J = 5.7 Hz), 58.6 (d, J = 11.4 Hz), 30.6 (d, J = 2.1 Hz), 28.8 (d, J = 2.2 Hz), 23.9 (d, J = 4.1 Hz), 23.6 (d, J = 5.8 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 16.8 (s). HRMS calcd for $C_{12}H_{24}O_3PS^+$ $[M+H]^+$, 279.1178; found, 279,1171.

***O,O*-diisopropyl *S*-((triisopropylsilyl)ethynyl) phosphorothioate (13)**



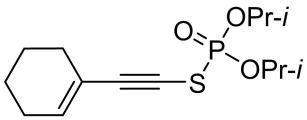
Yield: 27.6 mg, 73%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 4.92-4.87 (m, 2H), 1.44 (dd, J_1 = 3.42 Hz, J_2 = 6.18 Hz, 12H), 1.08-1.06 (m, 21H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 97.4 (d, J = 7.5 Hz), 86.0 (d, J = 11.1 Hz), 74.4 (d, J = 6.0 Hz), 24.0 (d, J = 4.3 Hz), 23.6 (d, J = 5.7 Hz), 18.7 (s), 11.5 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.9 (s). HRMS calcd for $C_{17}H_{36}O_3PSSi^+$ $[M+H]^+$, 379.1887; found, 379.1881.

***O,O*-diisopropyl *S*-((trimethylsilyl)ethynyl) phosphorothioate (14)**



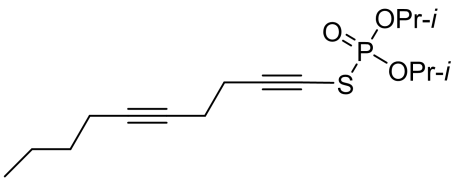
Yield: 21.8 mg, 74%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 4.91-4.85 (m, 2H), 1.42 (dd, J_1 = 5.94 Hz, J_2 = 12.1 Hz 12H), 0.16 (s, 9H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 100.6 (d, J = 7.3 Hz), 85.0 (d, J = 11.1 Hz), 74.7 (d, J = 6.0 Hz), 23.9 (d, J = 4.1 Hz), 23.6 (d, J = 6.4 Hz), 0.27(s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.1 (s). HRMS calcd for $C_{11}H_{24}O_3PSSi^+$ $[M+H]^+$, 295.0948; found, 295.0943.

***S*-(cyclohex-1-en-1-ylethynyl) *O,O*-diisopropyl phosphorothioate (15)**



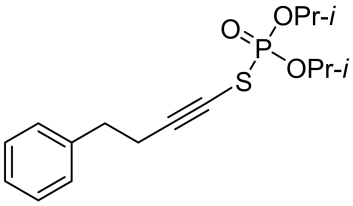
Yield: 21.8 mg, 72%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 6.14-6.12 (m, 1H), 4.91-4.85 (m, 2H), 2.69-2.08 (m, 4H), 1.62-1.55 (m, 4H), 1.42 (d, J = 5.94 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 137.0 (d, J = 4.3 Hz), 120.6 (d, J = 4.3 Hz), 94.2 (d, J = 8.7 Hz), 74.5 (d, J = 6.2 Hz), 66.9 (d, J = 12.1 Hz), 28.9 (s), 25.8 (s), 24.0 (d, J = 4.1 Hz), 23.6 (d, J = 6.3 Hz). 22.3 (s), 21.5 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.9 (s). HRMS calcd for $C_{14}H_{23}NaO_3PS^+$ $[M+Na]^+$, 325.0998; found, 325.0995.

***S*-(deca-1,5-diyn-1-yl) *O*,*O*-diisopropyl phosphorothioate (16)**



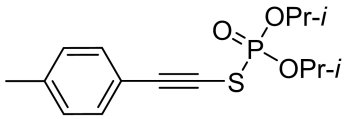
Yield: 20.1 mg, 61%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 4.89-4.85 (m, 2H), 2.48-2.45 (m, 2H), 2.37-2.34 (m, 2H), 2.15-2.12 (m, 2H), 1.46-1.37 (m, 3H), 0.90 (t, *J* = 7.26 Hz, 16H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 92.3 (d, *J* = 8.6 Hz), 81.7 (s), 77.9 (s), 74.3 (d, *J* = 5.7 Hz), 60.8 (d, *J* = 11.9 Hz), 31.0 (s), 23.8 (d, *J* = 3.7 Hz), 23.5 (d, *J* = 5.6 Hz), 21.9 (s), 20.7 (d, *J* = 3.0 Hz). 18.8 (d, *J* = 2.3 Hz), 18.4 (s), 13.6 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 17.0 (s). HRMS calcd for $C_{16}H_{27}NaO_3PS^+$ $[M+Na]^+$, 353.1311; found, 353.1317

***O*,*O*-diisopropyl *S*-(4-phenylbut-1-yn-1-yl) phosphorothioate (17)**



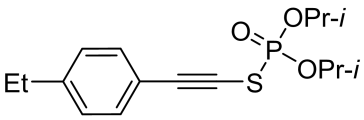
Yield: 18.6 mg, 57%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.28 (t, *J* = 7.44 Hz, 2H), 7.19 (t, *J* = 7.94 Hz, 3H), 4.85-4.76 (m, 2H), 2.81 (t, *J* = 7.50 Hz, 2H), 2.59-2.55 (m, 2H), 1.36 (d, *J* = 6.81 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 140.2 (s), 128.5 (s), 128.4 (s), 126.7 (s), 93,1 (d, *J* = 8.1 Hz), 74.3 (d, *J* = 5.6 Hz), 60.5 (d, *J* = 11.3 Hz), 34.8 (d, *J* = 2.1 Hz), 23.9 (d, *J* = 4.1 Hz), 23.5 (d, *J* = 5.5 Hz), 22.1 (d, *J* = 3.1 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 16.9 (s). HRMS calcd for $C_{16}H_{24}O_3PS^+$ $[M+H]^+$,327.1178; found, 327.1171.

***O*,*O*-diisopropyl *S*-(*p*-tolylethynyl) phosphorothioate (18)**



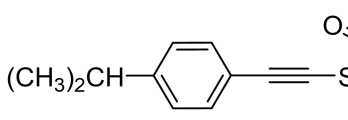
Yield: 22.1 mg, 71%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.30 (d, *J* = 8.03 Hz, 2H), 7.10 (d, *J* = 7.92 Hz, 2H), 4.94-4.91 (m, 2H), 2.34 (s, 3H), 1.44 (t, *J* = 5.44 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 139.2 (s), 131.9 (d, *J* = 2.5 Hz), 129.2 (s), 119.6 (d, *J* = 4.1 Hz), 92.3 (d, *J* = 8.7 Hz), 74.6 (d, *J* = 5.8 Hz), 69.5 (d, *J* = 11.7 Hz), 24.0 (d, *J* = 4.1 Hz), 23.6 (d, *J* = 5.8 Hz), 21.6 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.5 (s). HRMS calcd for $C_{15}H_{21}NaO_3PS^+$ $[M+Na]^+$, 335.0841; found, 335.0848.

***S*-((4-ethylphenyl)ethynyl) *O*,*O*-diisopropyl phosphorothioate (19)**



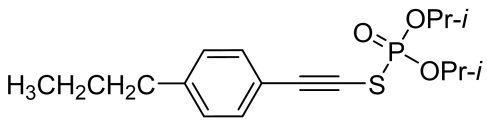
Yield: 23.8 mg, 73%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.33 (d, *J* = 7.98 Hz, 2H), 7.14 (d, *J* = 8.06 Hz, 2H), 4.96-4.90 (m, 2H), 2.66-2.62 (m, 2H), 1.44 (t, *J* = 5.61 Hz, 12H), 1.22 (t, *J* = 7.56 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 145.5 (s), 132.0 (d, *J* = 2.9 Hz), 128.1 (s), 119.9 (d, *J* = 4.0 Hz), 94.4 (d, *J* = 8.8 Hz), 74.7 (d, *J* = 6.1 Hz), 69.5 (d, *J* = 12.0 Hz), 29.0 (s), 24.0 (d, *J* = 3.6 Hz), 23.7 (d, *J* = 5.7 Hz), 15.4 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.5 (s). HRMS calcd for $C_{16}H_{23}NaO_3PS^+$ $[M+Na]^+$, 349.0998; found, 349.0993.

***O*,*O*-diisopropyl *S*-((4-isopropylphenyl)ethynyl) phosphorothioate (20)**



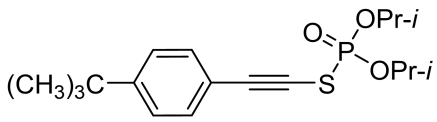
Yield: 25.5 mg, 75%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.34 (d, *J* = 8.04 Hz, 2H), 7.16 (d, *J* = 8.10 Hz, 2H), 4.95-4.91 (m, 2H), 2.91-2.87 (m, 1H), 1.45 (t, *J* = 5.70 Hz, 12H). 1.23 (d, *J* = 6.96 Hz, 6H).^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 150.1 (s), 132.0 (d, *J* = 2.6 Hz), 126.7 (s), 120.0 (d, *J* = 3.8 Hz), 92.4 (d, *J* = 8.4 Hz), 74.6 (d, *J* = 6.3 Hz), 69.5 (d, *J* = 12.0 Hz), 34.2 (s), 24.0 (d, *J* = 3.8 Hz), 23.8 (s), 23.7 (d, *J* = 5.9 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.5 (s). HRMS calcd for $C_{17}H_{25}O_3PS^+$ $[M+H]^+$, 341.1335; found, 341.1333.

***O,O*-diisopropyl *S*-((4-propylphenyl)ethynyl) phosphorothioate (21)**



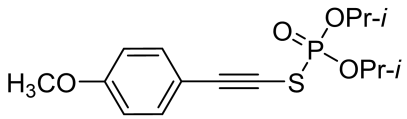
Yield: 23.5 mg, 69%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.33 (d, *J* = 8.03 Hz, 2H), 7.11 (d, *J* = 8.11 Hz, 2H), 4.95-4.91 (m, 2H), 2.57 (t, *J* = 7.56 Hz, 2H), 1.64-1.60 (m, 2H), 1.44 (t, *J* = 5.90 Hz, 12H), 0.92 (t, *J* = 7.35, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 144.0 (s), 131.9 (d, *J* = 3.0 Hz), 128.7 (s), 119.9 (d, *J* = 3.7 Hz), 92.4 (d, *J* = 8.6 Hz), 74.7 (d, *J* = 6.1 Hz), 69.6 (d, *J* = 12.0 Hz), 30.1 (s), 24.4 (s), 24.0 (d, *J* = 3.7 Hz), 23.7 (d, *J* = 5.9 Hz), 13.9 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.5 (s). HRMS calcd for $C_{17}H_{25}NaO_3PS^+$ $[M+Na]^+$, 363.1154; found, 363.1159.

***S*-((4-(tert-butyl)phenyl)ethynyl) *O,O*-diisopropyl phosphorothioate (22)**



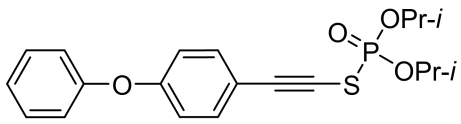
Yield: 27.2 mg, 77%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.36-7.32 (m, 4H), 4.95-4.92 (m, 2H), 1.45 (t, *J* = 5.60 Hz, 12H). 1.30 (s, 9H).^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 152.4 (s), 131.7 (d, *J* = 2.5 Hz), 125.5 (s), 119.7 (d, *J* = 4.0 Hz), 92.4 (d, *J* = 8.2 Hz), 74.7 (d, *J* = 5.9 Hz), 69.6 (d, *J* = 12.0 Hz), 35.0 (s), 31.2 (s), 24.0 (d, *J* = 3.7 Hz), 23.7 (d, *J* = 6.2 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.3 (s). HRMS calcd for $C_{18}H_{27}NaO_3PS^+$ $[M+Na]^+$, 377.1311; found, 377.1313.

***O,O*-diisopropyl *S*-((4-methoxyphenyl)ethynyl) phosphorothioate (23)**



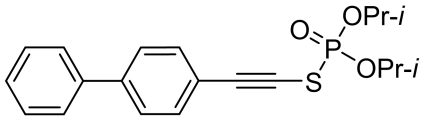
Yield: 22.9 mg, 68%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.36 (d, *J* = 8.59 Hz, 2H), 6.83 (d, *J* = 8.70 Hz, 2H), 4.94-4.91 (m, 2H), 3.81 (s, 3H), 1.44 (t, *J* = 6.15 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 160.2 (s), 133.7 (d, *J* = 2.3 Hz), 114.8 (d, *J* = 3.6 Hz), 114.2 (s), 92.2 (d, *J* = 8.2 Hz), 74.6 (d, *J* = 5.9 Hz), 68.6 (d, *J* = 11.6 Hz), 55.5 (s), 24.0 (d, *J* = 4.1 Hz), 23.7 (d, *J* = 6.2 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.7 (s). HRMS calcd for $C_{12}H_{21}NaO_4PS^+$ $[M+Na]^+$, 351.0790; found, 351.0785.

***O,O*-diisopropyl *S*-((4-phenoxyphenyl)ethynyl) phosphorothioate (24)**



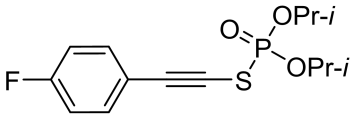
Yield: 24.2 mg, 62%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.37-7.33 (m, 4H), 7.13 (t, *J* = 7.32 Hz, 1H), 7.00 (d, *J* = 8.34 Hz, 2H), 6.89 (d, *J* = 8.64 Hz, 2H), 4.94-4.90 (m, 2H), 1.43 (t, *J* = 6.00 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 158.3 (s), 156.1 (s), 133.7 (d, *J* = 3.0 Hz), 130.0 (s), 124.2 (s), 119.7 (s), 118.2 (s), 117.0 (s), 91.8 (d, *J* = 8.3 Hz), 74.6 (d, *J* = 6.2 Hz), 69.6 (d, *J* = 12.2 Hz), 23.9 (d, *J* = 4.2 Hz), 23.6 (d, *J* = 5.8 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.5 (s). HRMS calcd for $C_{20}H_{23}NaO_4PS^+$ $[M+Na]^+$, 413.0947; found, 413.0955.

***S*-([1,1'-biphenyl]-4-ylethynyl) *O,O*-diisopropyl phosphorothioate (25)**



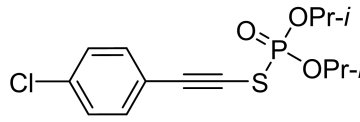
Yield: 18.7 mg, 50%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.59-7.54 (m, 4H), 7.50-7.43 (m, 4H), 7.38-7.34 (m, 1H), 5.00-4.92 (m, 2H), 1.47 (t, *J* = 5.28 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 141.7 (s), 140.2 (s), 132.3 (d, *J* = 2.3 Hz), 129.0 (s), 127.9 (s), 127.2 (s), 127.1 (s), 121.5 (d, *J* = 3.7 Hz), 92.1 (d, *J* = 8.7 Hz), 74.7 (d, *J* = 6.2 Hz), 71.2 (d, *J* = 11.6 Hz), 24.0 (d, *J* = 4.1 Hz), 23.7 (d, *J* = 6.1 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.5 (s). HRMS calcd for $C_{20}H_{23}NaO_3PS^+$ $[M+Na]^+$, 397.0998; found, 397.0992.

***S*-((4-fluorophenyl)ethynyl) *O,O*-diisopropyl phosphorothioate (26)**



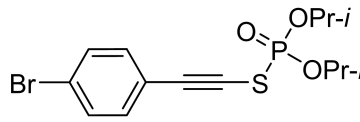
Yield: 21.2 mg, 67%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.40-7.38 (m, 2H), 6.99 (d, J = 8.58 Hz, 2H), 4.94-4.89 (m, 2H), 1.43 (dd, J_1= 3.87 Hz, J_2= 5.85 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 162.9 (d, J = 250.6 Hz), 134.0 (dd, J_1 = 2.8 Hz, J_2 = 8.7 Hz), 118.8 (t, J = 3.7 Hz), 115.9 (d, J = 22.2 Hz), 91.1 (d, J = 8.4 Hz), 74.7 (d, J = 5.8 Hz), 70.4 (d, J = 12.1 Hz), 23.9 (d, J = 4.2 Hz), 23.6 (d, J = 5.8 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 14.7 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ (ppm) -109.5 (s). HRMS calcd for $C_{14}H_{18}FNaO_3PS^+$ $[M+Na]^+$, 339.0591; found, 339.0590.

***S*-((4-chlorophenyl)ethynyl) *O,O*-diisopropyl phosphorothioate (27)**



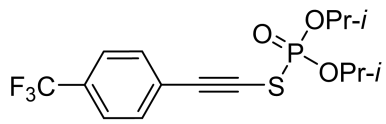
Yield: 25.6 mg, 77%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.33 (d, J = 8.43 Hz, 2H), 7.28 (d, J = 8.60 Hz, 2H), 4.94-4.90 (m, 2H), 1.44 (t, J = 6.18 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 135.1 (s), 133.1 (d, J = 3.2 Hz), 128.9 (s), 121.2 (d, J = 4.1 Hz), 91.0 (d, J = 8.8 Hz), 74.8 (d, J = 6.4 Hz), 72.0 (d, J = 11.5 Hz), 24.0 (d, J = 4.3 Hz), 23.6 (d, J = 5.7 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.2 (s). HRMS calcd for $C_{14}H_{18}ClNaO_3PS^+$ $[M+Na]^+$, 355.0295; found, 355.0294.

***S*-((4-bromophenyl)ethynyl) *O,O*-diisopropyl phosphorothioate (28)**



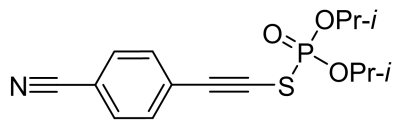
Yield: 28.2 mg, 75%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.45 (d, J = 8.40 Hz, 2H), 7.28 (d, J = 8.28 Hz, 2H), 4.95-4.91 (m, 2H), 1.45 (d, J = 6.24 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 133.2 (d, J = 2.4 Hz), 131.8 (s), 123.2 (s), 121.6 (d, J = 3.9 Hz), 91.1 (d, J = 8.4 Hz), 74.7 (d, J = 5.9 Hz), 72.2 (d, J = 11.6 Hz), 23.9 (d, J = 3.6 Hz), 23.6 (d, J = 6.0 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.0 (s). HRMS calcd for $C_{14}H_{18}BrNaO_3PS^+$ $[M+Na]^+$, 398.9790; found, 398.9798.

***O,O*-diisopropyl *S*-((4-(trifluoromethyl)phenyl)ethynyl) phosphorothioate (29)**



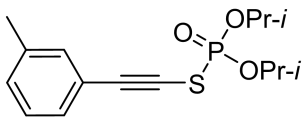
Yield: 19.4 mg, 53%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.56 (d, J = 8.27 Hz, 2H), 7.50 (d, J = 8.12 Hz, 2H), 4.96-4.90 (m, 2H), 1.45 (d, J = 6.18 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 131.9 (d, J = 3.0 Hz), 130.5 (q, J = 32.8 Hz), 126.5 (s), 125.5 (q, J = 4.0 Hz), 123.9 (q, J = 272.2 Hz), 90.8 (d, J = 8.5 Hz), 74.9 (d, J = 5.9 Hz), 74.2 (d, J = 11.9 Hz), 24.0 (d, J = 4.0 Hz), 23.6 (d, J = 6.2 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 14.3 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ (ppm) -62.9 (s). HRMS calcd for $C_{15}H_{28}F_3NaO_3PS^+$ $[M+Na]^+$, 389.0559; found, 389.0553.

***S*-((4-cyanophenyl)ethynyl) *O,O*-diisopropyl phosphorothioate (30)**



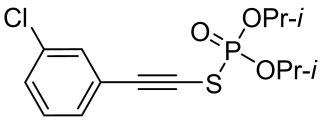
Yield: 14.9 mg, 46%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.58 (d, J = 8.16 Hz, 2H), 7.47 (d, J = 8.16 Hz, 2H), 4.94-4.88 (m, 2H), 1.43 (dd, J_1 = 2.25 Hz, J_2 = 6.09 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 132.2 (s), 132.1 (d, J = 3.2 Hz), 127.5 (d, J = 3.8 Hz), 118.4 (s), 112.0 (s), 90.5 (d, J = 8.1 Hz), 76.7 (d, J = 11.5 Hz), 75.0 (d, J = 6.3 Hz), 23.9 (d, J = 4.1 Hz), 23.6 (d, J = 5.9 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 14.5 (s). HRMS calcd for $C_{15}H_{18}NNaO_3PS^+$ $[M+Na]^+$, 346.0637; found, 346.0634.

***O,O*-diisopropyl *S*-(*m*-tolylethynyl) phosphorothioate (32)**



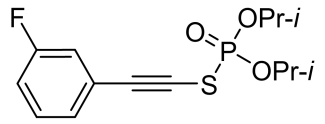
Yield: 20.6 mg, 66%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.23-7.18 (m, 3H), 7.14 (d, J = 7.36 Hz, 1H), 4.96-4.91 (m, 2H), 2.32 (s, 3H), 1.45 (t, J = 5.31 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 138.2 (s), 132.4 (d, J = 2.3 Hz), 129.9 (s), 129.0 (d, J = 3.1 Hz), 128.4 (s) 122.5 (d, J = 4.1 Hz), 92.4 (d, J = 8.4 Hz), 74.7 (d, J = 6.1 Hz), 70.1 (d, J = 12.0 Hz), 24.0 (d, J = 3.9 Hz), 23.7 (d, J = 5.6 Hz), 21.3 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.5 (s). HRMS calcd for $C_{15}H_{21}NaO_3PS^+$ $[M+Na]^+$, 335.0841; found, 335.0845.

***S*-((3-chlorophenyl)ethynyl) *O,O*-diisopropyl phosphorothioate (33)**



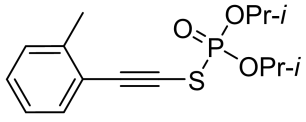
Yield: 23.6 mg, 71%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.38 (s, 1H), 7.31-7.28 (m, 2H), 7.24 (t, J = 7.86 Hz, 1H), 4.95-4.80 (m, 2H), 1.45 (dd, J_1 = 0.99 Hz, J_2 = 6.15 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 134.4 (s), 131.6 (d, J = 3.1 Hz), 130.0 (d, J = 3.1 Hz), 129.8 (s), 129.2 (s) 124.4 (d, J = 4.0 Hz), 90.7 (d, J = 8.7 Hz), 74.8 (d, J = 5.8 Hz), 72.6 (d, J = 11.9 Hz), 24.0 (d, J = 4.2 Hz), 23.6 (d, J = 5.7 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 14.9 (s). HRMS calcd for $C_{14}H_{18}ClNaO_3PS^+$ $[M+Na]^+$, 355.0295; found, 355.0296.

***S*-((3-fluorophenyl)ethynyl) *O,O*-diisopropyl phosphorothioate (34)**



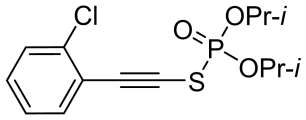
Yield: 19.0 mg, 60%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.29-7.25 (m, 1H), 7.19 (d, J = 7.68 Hz, 1H), 7.09 (d, J = 9.30 Hz, 1H), 7.05-7.02 (m, 1H), 4.95-4.91 (m, 2H), 1.45 (dd, J_1 = 2.10 Hz, J_2 = 6.18 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 162.4 (d, J = 246.9 Hz), 130.2 (d, J = 8.8 Hz), 127.8 (t, J = 2.6 Hz), 124.5 (dd, J_1 = 9.3 Hz, J_2 = 4.0 Hz), 118.6 (dd, J_1 = 2.8 Hz, J_2 = 22.7 Hz), 116.3 (d, J = 21.1 Hz), 90.9 (d, J = 8.2 Hz), 74.8 (d, J = 5.8 Hz), 72.3 (d, J = 11.9 Hz), 24.0 (d, J = 4.3 Hz), 23.6 (d, J = 5.9 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.0 (s). ^{19} F NMR (376 MHz, $CDCl_3$) δ (ppm) -112.6 (s). HRMS calcd for $C_{14}H_{18}FNaO_3PS^+$ $[M+Na]^+$, 339.0591; found, 339.0594.

***O,O*-diisopropyl *S*-(*o*-tolylethynyl) phosphorothioate (35)**



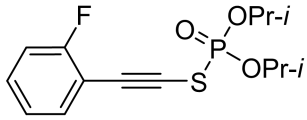
Yield: 19.0 mg, 61%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.36 (d, J = 7.62 Hz, 1H), 7.21 (t, J = 7.32 Hz, 1H), 7.17 (d, J = 7.31 Hz, 1H), 7.11 (d, J = 7.44 Hz, 1H), 4.96-4.90 (m, 2H), 2.42 (s, 3H), 1.43 (dd, J_1 = 3.15 Hz, J_2 = 6.21 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 140.8 (d, J = 2.1 Hz), 132.1 (d, J = 3.1 Hz), 129.6 (s), 128.8 (s), 125.6 (s) 122.4 (d, J = 3.5 Hz), 91.2 (d, J = 8.6 Hz), 74.5 (d, J = 5.7 Hz), 73.9 (d, J = 11.9 Hz), 23.9 (d, J = 4.2 Hz), 23.6 (d, J = 5.9 Hz), 20.6 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.7 (s). HRMS calcd for $C_{15}H_{21}NaO_3PS^+$ $[M+Na]^+$, 335.0841; found, 335.0838.

***S*-((2-chlorophenyl)ethynyl) *O,O*-diisopropyl phosphorothioate (36)**



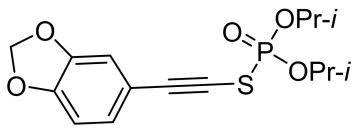
Yield: 21.6 mg, 65%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.45-7.43 (m, 1H), 7.38 (d, *J* = 8.04 Hz, 1H), 7.27-7.24 (m, 1H), 7.20 (t, *J* = 7.54 Hz, 1H), 4.98-4.93 (m, 2H), 1.45 (t, *J* = 6.72 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 136.3 (d, *J* = 2.9 Hz), 133.7 (d, *J* = 2.5 Hz), 129.9 (s), 129.5 (s), 126.6 (s), 122.7 (d, *J* = 4.0 Hz), 88.9 (d, *J* = 8.7 Hz), 76.4 (d, *J* = 12.0 Hz), 74.9 (d, *J* = 6.0 Hz), 24.0 (d, *J* = 4.3 Hz), 23.7 (d, *J* = 5.8 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 14.6 (s). HRMS calcd for $C_{14}H_{18}ClNaO_3PS^+$ $[M+Na]^+$, 355.0295; found, 355.0297.

***S*-((2-fluorophenyl)ethynyl) *O,O*-diisopropyl phosphorothioate (37)**



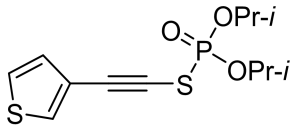
Yield: 16.8 mg, 53%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.37 (t, *J* = 7.32 Hz, 1H), 7.31-7.37 (m, 1H), 7.07-7.02 (m, 2H), 4.94-4.91 (m, 2H), 1.42 (t, *J* = 6.30 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 163.3 (dd, J_1 = 252.8 Hz, J_2 = 2.2 Hz), 133.7 (d, *J* = 2.6 Hz), 130.7 (d, *J* = 7.9 Hz), 124.1 (d, *J* = 3.5 Hz), 115.7 (d, *J* = 20.8 Hz), 111.3 (dd, J_1 = 3.7 Hz, J_2 = 15.6 Hz), 85.5 (d, *J* = 8.5 Hz), 76.2 (dd, J_1 = 11.9 Hz, J_2 = 3.2 Hz), 74.9 (d, *J* = 6.4 Hz), 23.9 (d, *J* = 3.7 Hz), 23.5 (d, *J* = 6.0 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 14.5 (s). ^{19}F NMR (376 MHz, $CDCl_3$) δ (ppm) -109.5 (s). HRMS calcd for $C_{14}H_{18}FNaO_3PS^+$ $[M+Na]^+$, 339.0591; found, 339.0585.

***S*-(benzo[d][1,3]dioxol-5-ylethynyl) *O,O*-diisopropyl phosphorothioate (38)**



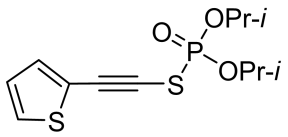
Yield: 20.9 mg, 61%. Bright yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 6.94 (d, *J* = 7.98 Hz, 1H), 6.84 (s, 1H), 6.73 (d, *J* = 8.04 Hz, 1H), 5.96 (s, 2H), 4.94-4.88 (m, 2H), 1.43 (d, *J* = 5.56 Hz, 12H). ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 148.6 (s), 147.5 (s), 127.1 (d, *J* = 2.6 Hz), 115.9 (d, *J* = 3.7 Hz), 111.9 (d, *J* = 2.7 Hz), 108.6 (s), 101.6 (s), 92.1 (d, *J* = 8.7 Hz), 74.6 (d, *J* = 6.4 Hz), 68.7 (d, *J* = 12.0 Hz), 23.9 (d, *J* = 4.1 Hz), 23.6 (d, *J* = 5.7 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.5 (s). HRMS calcd for $C_{15}H_{19}NaO_5PS^+$ $[M+Na]^+$, 365.0583; found, 365.0580.

***O,O*-diisopropyl *S*-(thiophen-3-ylethynyl) phosphorothioate (39)**



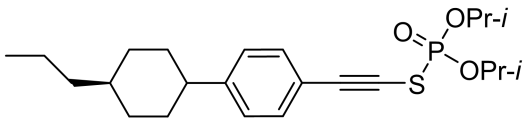
Yield: 13.4 mg, 44%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.46-7.45 (m, 1H), 7.25-7.34 (m, 1H), 7.08-7.07 (m, 1H), 4.93-4.89 (m, 2H), 1.43 (t, *J* = 5.85 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 130.2 (d, *J* = 3.6 Hz), 130.0 (s), 125.6 (s), 121.7 (d, *J* = 4.2 Hz), 87.3 (d, *J* = 8.7 Hz), 74.7 (d, *J* = 6.4 Hz), 70.1 (d, *J* = 11.7 Hz), 23.9 (d, *J* = 3.6 Hz), 23.6 (d, *J* = 6.3 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.4 (s). HRMS calcd for $C_{12}H_{17}NaO_3PS_2^+$ $[M+Na]^+$, 327.0249; found, 327.0246.

***O,O*-diisopropyl *S*-(thiophen-3-ylethynyl) phosphorothioate (40)**



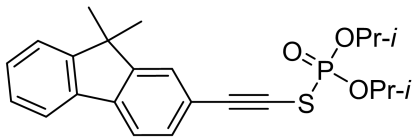
Yield: 12.5 mg, 41%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.29 (d, *J* = 5.16 Hz, 1H), 7.23 (dd, J_1 = 1.11 Hz, J_2 = 2.49 Hz, 1H), 6.97 (dd, J_1 = 3.72 Hz, J_2 = 5.04 Hz, 1H), 4.95-4.89 (m, 2H), 1.44 (t, *J* = 6.24 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 133.6 (d, *J* = 2.6 Hz), 128.5 (s), 127.2 (s), 122.8 (d, *J* = 4.6 Hz), 85.4 (d, *J* = 8.7 Hz), 75.2 (d, *J* = 12.1 Hz), 74.9 (d, *J* = 12.1 Hz), 23.9 (d, *J* = 3.7 Hz), 23.7 (d, *J* = 5.8 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 14.7 (s). HRMS calcd for $C_{12}H_{17}NaO_3PS_2^+$ $[M+Na]^+$, 327.0249; found, 327.0255.

***O,O*-diisopropyl *S*-((4-(4-propylcyclohexyl)phenyl)ethynyl) phosphorothioate (42)**



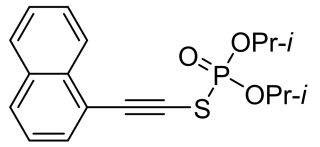
Yield: 30.4 mg, 72%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.33 (d, J = 8.10 Hz, 2H), 7.15 (d, J = 8.16 Hz, 2H), 4.96-4.90 (m, 2H), 2.45 (t, J = 12.27 Hz, 1H), 1.86 (d, J = 12.24 Hz, 4H), 1.45 (t, J = 5.37 Hz, 12H), 1.40-1.30 (m, 5H), 1.22-1.19 (m, 2H), 1.06-1.00 (m, 2H), 0.90 (t, J = 7.29 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 149.2 (s), 132.0 (d, J = 2.3 Hz), 127.1 (s), 120.0 (d, J = 4.0 Hz), 92.4 (d, J = 8.6 Hz), 74.6 (d, J = 6.2 Hz), 69.5 (d, J = 11.9 Hz), 44.7 (s), 39.8 (s), 37.1 (s), 34.2 (s), 33.6 (s), 24.0 (d, J = 3.6 Hz), 23.7 (d, J = 6.2 Hz), 20.1 (s), 14.5 (s). ^{1}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.5 (s). HRMS calcd for $C_{23}H_{35}NaO_3PS^+$ $[M+Na]^+$, 445.1937; found, 445.1942.

***S*-((9,9-dimethyl-9*H*-fluoren-2-yl)ethynyl) *O,O*-diisopropyl phosphorothioate (43)**



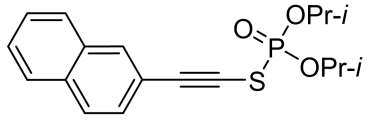
Yield: 26.9 mg, 65%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.71-7.0 (m, 1H), 7.65 (d, J = 7.80 Hz, 1H), 7.48 (s, 1H), 7.44-7.40 (m, 2H), 7.36-7.33 (m, 2H), 4.99-4.94 (m, 2H), 1.49-1.46 (m, 18H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 154.1 (s), 153.7 (s), 140.2 (s), 138.4 (s), 131.2 (d, J = 3.1 Hz), 128.0 (s), 127.3 (s), 126.3 (d, J = 3.0 Hz), 122.8 (s), 121.1 (d, J = 3.7 Hz), 120.5 (s), 120.1 (s), 93.1 (d, J = 8.8 Hz), 74.7 (d, J = 6.3 Hz), 70.3 (d, J = 12.1 Hz), 47.0 (s), 24.0 (d, J = 3.8 Hz), 23.7 (d, J = 5.6 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.6 (s). HRMS calcd for $C_{23}H_{27}FNaO_3PS^+$ $[M+Na]^+$, 437.1311; found, 437.1308.

***O,O*-diisopropyl *S*-(naphthalen-1-ylethynyl) phosphorothioate (44)**



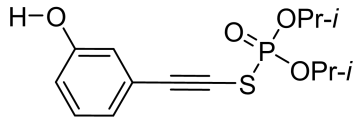
Yield: 20.9 mg, 60%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 8.32 (d, J = 8.34 Hz, 1H), 7.84 (t, J = 7.92 Hz, 2H), 7.65 (d, J = 7.08 Hz, 1H), 7.59-7.56 (m, 1H), 7.54-7.51 (m, 1H), 7.41 (dd, J_1 = 7.38 Hz, J_2 = 7.98 Hz, 1H), 5.02-4.97 (m, 2H), 1.47 (dd, J_1 = 2.58 Hz, J_2 = 6.18 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 133.6 (d, J = 2.0 Hz), 133.2 (s), 130.7 (d, J = 3.5 Hz), 129.3 (s), 128.4 (s), 127.1 (s), 126.7 (s), 126.2 (s), 125.3 (s), 120.4 (d, J = 4.1 Hz), 90.7 (d, J = 8.1 Hz), 75.3 (d, J = 12.0 Hz), 74.8 (d, J = 6.1 Hz), 24.0 (d, J = 4.3 Hz), 23.7 (d, J = 6.3 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 14.9 (s). HRMS calcd for $C_{18}H_{21}NaO_3PS^+$ $[M+Na]^+$, 371.0841; found, 327.0836.

***O,O*-diisopropyl *S*-(naphthalen-2-ylethynyl) phosphorothioate (45)**



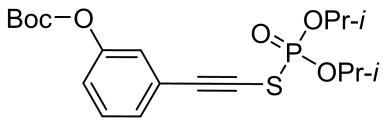
Yield: 22.6 mg, 65%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.94 (s, 1H), 7.81-7.75 (m, 3H), 7.51-7.43 (m, 3H), 5.01-4.93 (m, 2H), 1.47 (t, J = 6.24 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 133.0 (s), 132.9 (s), 132.0 (d, J = 3.3 Hz), 128.3 (d, J = 2.2 Hz), 128.2 (s), 127.9 (s) (two carbon), 127.1 (s), 126.8 (s), 119.9 (d, J = 4.0 Hz), 92.6 (d, J = 8.2 Hz), 74.8 (d, J = 6.4 Hz), 70.9 (d, J = 11.7 Hz), 24.0 (d, J = 4.1 Hz), 23.7 (d, J = 5.7 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 14.7 (s). HRMS calcd for $C_{18}H_{21}NaO_3PS^+$ $[M+Na]^+$, 371.0841; found, 327.0837.

***S*-((3-hydroxyphenyl)ethynyl) *O*,*O*-diisopropyl phosphorothioate (46)**



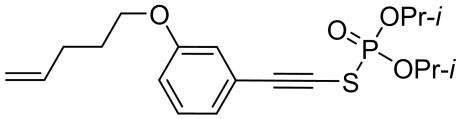
Yield: 10.7 mg, 34%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.31 (t, J = 7.92 Hz, 1H), 6.94 (d, J = 7.56 Hz, 1H), 6.89 (s, 1H), 6.83 (dd, J_1 = 2.40 Hz, J_2 = 8.16 Hz, 1H), 4.96-4.90 (m, 2H), 1.45 (dd, J_1 = 3.87 Hz, J_2 = 6.15 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 156.1 (s), 129.7 (s), 124.2 (d, J = 3.0 Hz), 123.6 (d, J = 4.0 Hz), 118.7 (d, J = 3.0 Hz), 116.7 (s), 92.4 (d, J = 8.7 Hz), 75.2 (d, J = 6.1 Hz), 69.9 (d, J = 12.0 Hz), 24.0 (d, J = 4.1 Hz), 23.7 (d, J = 5.6 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.0 (s). HRMS calcd for $C_{14}H_{19}NaO_4PS^+$ $[M+Na]^+$, 337.0634; found, 337.0632.

***tert*-butyl (3-(((diisopropoxyphosphoryl)thio)ethynyl)phenyl) carbonate (47)**



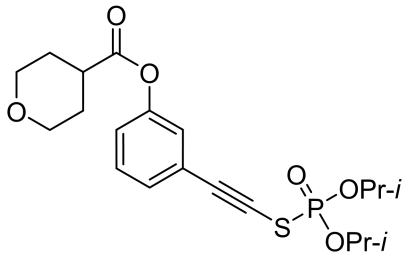
Yield: 31.9 mg, 77%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.29 (t, J = 7.94 Hz, 1H), 7.25 (d, J = 7.70 Hz, 1H), 7.20 (s, 1H), 7.14 (d, J = 8.01 Hz, 1H), 4.94-4.88 (m, 2H), 1.54 (s, 9H), 1.43 (dd, J_1 = 2.03 Hz, J_2 = 6.16 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 151.6 (s), 150.9 (s), 129.5 (s), 129.2 (d, J = 3.0 Hz), 124.5 (d, J = 2.8 Hz), 123.9 (d, J = 3.9 Hz), 122,2 (s), 91.1 (d, J = 8.5 Hz), 84.0 (s), 74.8 (d, J = 6.1 Hz), 71.9 (d, J = 11.5 Hz), 27.7 (s), 23.9 (d, J = 4.2 Hz), 23.6 (d, J = 5.9 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.0 (s). HRMS calcd for $C_{19}H_{27}NaO_6PS^+$ $[M+Na]^+$, 437.1158; found, 437.1152.

***O*,*O*-diisopropyl *S*-((3-(pent-4-en-1-yloxy)phenyl)ethynyl) phosphorothioate (48)**



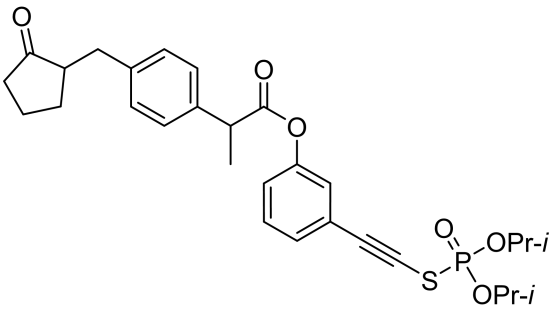
Yield: 28.7 mg, 75%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.20 (t, J = 7.98 Hz, 1H), 6.99 (d, J = 7.52 Hz, 1H), 6.92 (s, 1H), 6.89-6.86 (m, 1H), 5.89-5.79 (m, 1H), 5.08-4.89 (m, 4H), 3.94 (t, J = 6.44 Hz, 2H), 2.25-2.20 (m, 2H), 1.90-1.84 (m, 2H), 1.45 (dd, J_1= 2.56 Hz, J_2= 6.16 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 158.9 (s), 137.8 (s), 129.6 (s), 124.3 (d, J = 2.9 Hz), 123.6 (d, J = 3.7 Hz), 117.5 (d, J = 2.9 Hz), 115.9 (s), 115.4 (s), 92.2 (d, J = 8.4 Hz), 74.7 (d, J = 6.1 Hz), 70.4 (d, J = 11.9 Hz), 67.4 (s), 30.2 (s), 28.4 (s), 24.0 (d, J = 3.9 Hz), 23.7 (d, J = 5.9 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 14.8 (s). HRMS calcd for $C_{19}H_{27}NaO_3PS^+$ $[M+Na]^+$, 405.1260; found, 405.1256.

3-(((diisopropoxyphosphoryl)thio)ethynyl)phenyl (tetrahydro-2*H*-pyran-4-yl) carbonate (49)



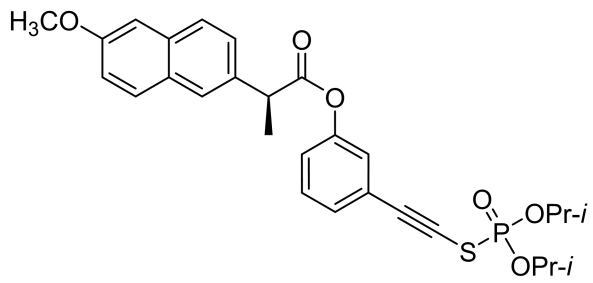
Yield: 34.1 mg, 80%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.35-7.28 (m, 2H), 7.14 (s, 1H), 7.07 (d, J = 8.04 Hz, 1H), 4.97-4.91 (m, 2H), 4.06-4.01 (m, 2H), 3.54-3.50 (m, 2H), 2.84-2.79 (m, 1H), 2.01-1.99 (m, 2H), 1.96-1.89 (m, 2H), 1.46 (dd, J_1 = 6.24 Hz, J_2 = 0.48 Hz, 12 H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 172.9 (s), 150.5 (s), 129.6 (s), 129.4 (d, J = 2.4 Hz), 124.7 (d, J = 3.1 Hz), 124.0 (d, J = 3.5 Hz), 122.4 (s), 91.1 (d, J = 8.7 Hz), 74.8 (d, J = 5.7 Hz), 72.1 (d, J = 11.6 Hz), 67.1 (s), 40.3 (s), 28.6 (s), 23.9 (d, J = 4.0 Hz), 23.6 (d, J = 5.7 Hz). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 15.1 (s). HRMS calcd for $C_{20}H_{27}NaO_6PS^+$ $[M+Na]^+$, 449.1158; found, 449.1153.

3-(((diisopropoxyphosphoryl)thio)ethynyl)phenyl 2-(4-((2-oxocyclopentyl)methyl)phenyl)propanoate (50)



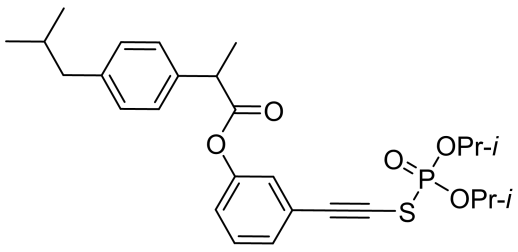
Yield: 35.8 mg, 66%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.29-7.23 (m, 4H), 7.17 (d, J = 8.10 Hz, 2H), 7.04 (s, 1H), 6.99-6.97 (m, 1H), 4.98-4.88 (m, 2H), 3.92 (q, J = 7.14 Hz, 1H), 3.14 (dd, J_1 = 4.14 Hz, J_2 = 13.98 Hz, 1H), 2.53 (dd, J_1 = 9.54 Hz, J_2 = 13.92 Hz, 1H), 2.37-2.32 (m, 2H), 2.14-2.08 (m, 2H), 1.99-1.93 (m, 1H), 1.77-1.70 (m, 1H), 1.59 (d, J = 7.20 Hz, 3H), 1.57-1.52 (m, 1H), 1.49 (dd, J_1 = 1.41 Hz, J_2 = 6.21 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 220..2 (s), 172.9 (s), 150.7 (s), 139.4 (s), 137.7 (s), 129.47 (s), 129.45 (s), 129.3 (d, J = 3.0 Hz), 127.6 (s), 124.7 (s), 123.9 (d, J = 3.5 Hz), 122.3 (s), 91.1 (d, J = 8.3 Hz), 74.8 (d, J = 6.6 Hz), 71.9 (d, J = 11.1 Hz), 51.1 (s), 45.3 (s), 38.3 (s), 35.3 (s), 29.4 (s), 23.9 (d, J = 3.5 Hz), 23.6 (d, J = 5.8 Hz), 20.6 (s), 18.6 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 14.8 (s). HRMS calcd for $C_{29}H_{35}NaO_6PS^+$ $[M+Na]^+$, 565.1784; found, 565.1778.

3-(((diisopropoxyphosphoryl)thio)ethynyl)phenyl (*S*)-2-(6-methoxynaphthalen-2-yl)propanoate (51)



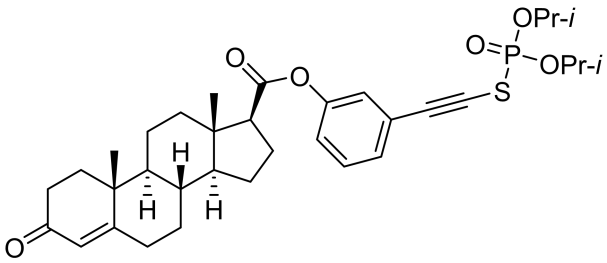
Yield: 36.8 mg, 70%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.76-7.24 (m, 3H), 7.48-7.47 (m, 1H), 7.26-7.22 (m, 2H), 7.17-7.14 (m, 2H), 7.02 (s, 1H), 6.98-6.96 (m, 1H), 4.94-4.87 (m, 2H), 4.08 (q, J = 7.10 Hz, 1H), 3.92 (s, 3H), 1.68 (d, J = 7.14 Hz, 3H), 1.41 (t, J = 6.30 Hz, 12H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 173.0 (s), 157.9 (s), 150.7 (s), 135.0 (s), 134.0 (s), 129.5 (s), 129.4 (s), 129.3 (d, J = 2.5 Hz), 129.1 (s), 127.6 (s), 126.3 (s), 126.1 (s), 124.7 (d, J = 3.1 Hz), 123.9 (d, J = 4.0 Hz), 122.4 (s), 119.3 (s), 105.7 (s), 91.1 (d, J = 8.7 Hz), 74.8 (d, J = 6.4 Hz), 72.0 (d, J = 11.9 Hz), 55.5 (s), 45.6 (s), 23.9 (d, J = 4.2 Hz), 23.6 (d, J = 6.0 Hz), 18.5 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 14.3 (s). HRMS calcd for $C_{28}H_{31}NaO_6PS^+$ $[M+Na]^+$, 549.1471; found, 549.1470.

3-(((diisopropoxyphosphoryl)thio)ethynyl)phenyl 2-(4-isobutylphenyl)propanoate (52)



Yield: 34.7 mg, 69%. Bright yellow oil.^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.31-7.26 (m, 4H), 7.17-7.15 (m, 2H), 7.07 (s, 1H), 7.01-6.99 (m, 1H), 4.97-4.91 (m, 2H), 3.95 (q, J = 7.12 Hz, 1H), 2.49 (d, J = 7.20 Hz, 2H), 1.91-1.87 (m, 1H), 1.62 (d, J = 7.14 Hz, 3H), 1.45 (dd, J_1 = 1.92 Hz, J_2 = 6.18 Hz, 12H), 0.93 (d, J = 6.60 Hz, 6H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 173.1 (s), 150.8 (s), 141.1 (s), 137.1(s), 129.7 (s), 129.5 (s), 129.3 (d, J = 2.8 Hz), 127.3 (s), 124.7 (d, J = 3.1 Hz), 123.9 (s), 122.4 (s), 91.2 (d, J = 8.6 Hz), 74.9 (d, J = 6.3 Hz), 71.8 (d, J = 12.1 Hz), 45.3 (s), 45.2 (s), 30.3 (s), 23.7 (d, J = 3.9 Hz), 23.6 (d, J = 5.7 Hz), 22.5 (s), 18.6 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 14.9 (s). HRMS calcd for $C_{27}H_{35}NaO_5PS^+$ $[M+Na]^+$, 525.1835; found, 525.1838.

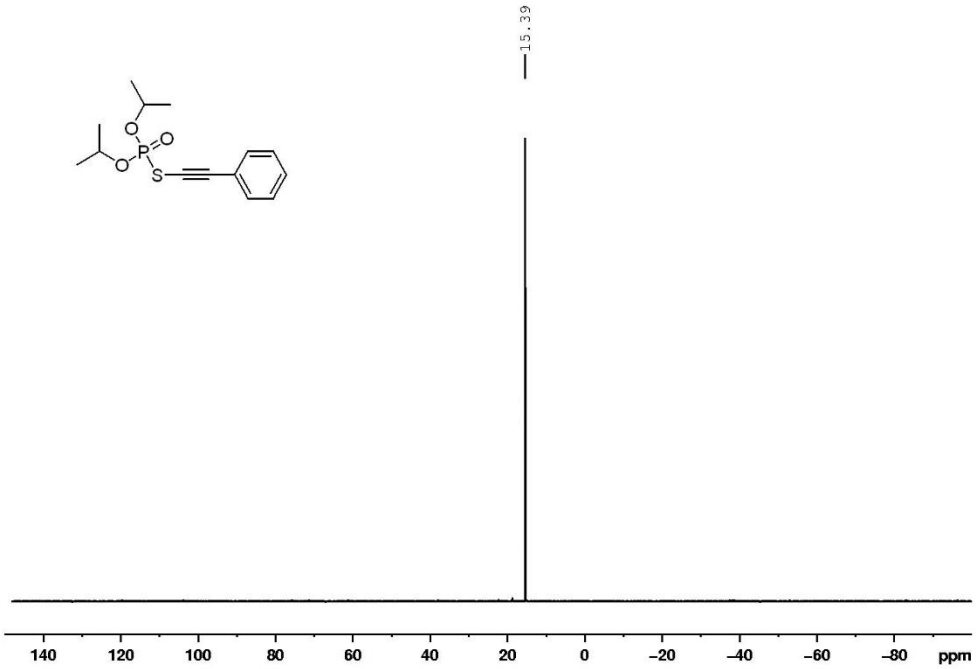
3-(((diisopropoxyphosphoryl)thio)ethynyl)phenyl (8S,9S,10R,13S,14S,17S)-10,13-dimethyl-3-oxo-2,3,6,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1H-cyclopenta[a]phenanthrene-17-carboxylate (53)



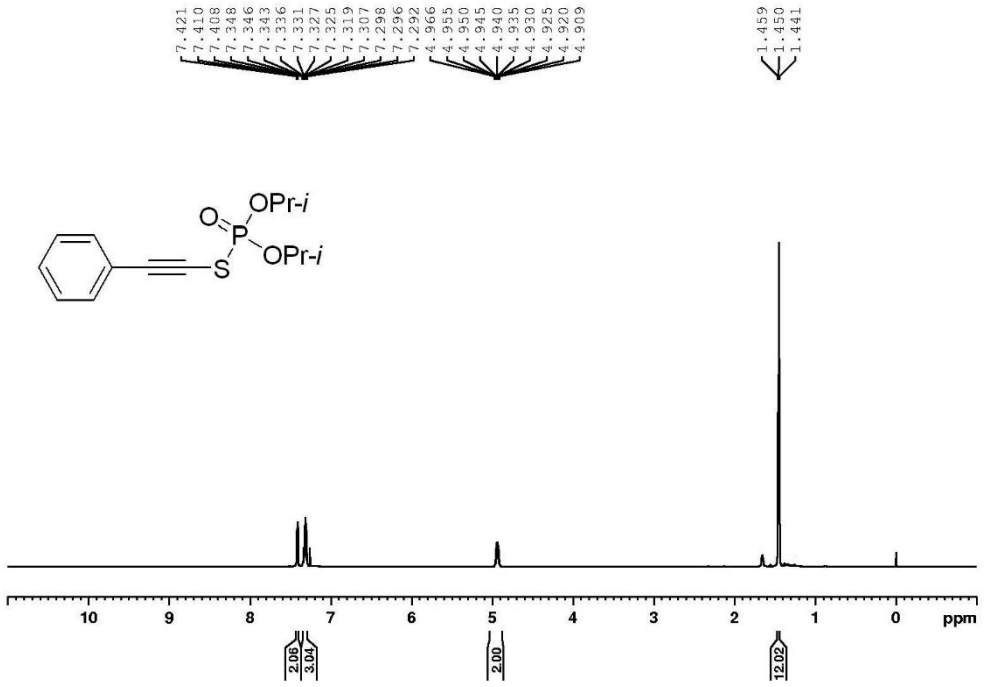
Yield: 32.5 mg, 52%. Bright yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.32-7.27 (m, 2H), 7.11 (s, 1H), 7.06 (d, *J* = 8.04 Hz, 1H), 5.74 (s, 1H), 4.95-4.90 (m, 2H), 2.60 (t, *J* = 9.42 Hz, 1H), 2.49-2.39 (m, 2H), 2.37-2.33 (m, 1H), 2.31-2.28 (m, 1H), 2.23-2.17 (m, 2H), 2.06-2.03 (m,1H), 1.95-1.88 (m, 2H), 1.81-1.76 (m, 1H), 1.75-1.70 (m, 2H), 1.67-1.57 (m, 2H), 1.44 (d, *J* = 6.18 Hz, 12H), 1.39-1.34 (m, 2H), 1.25-1.22 (m, 1H), 1.20 (s, 3H), 1.13-1.06 (m, 1H), 1.03-0.98 (m, 1H), 0.85 (s, 3H).^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm) 199.6 (s), 172.3 (s), 171.0 (s), 150.7 (s), 129.5 (s), 129.2 (d, *J* = 2.5 Hz), 124.9 (d, *J* = 2.7 Hz), 124.1 (s), 124.0 (d, *J* = 3.6 Hz), 122.6 (s), 91.2 (d, *J* = 8.3 Hz), 74.8 (d, *J* = 6.2 Hz), 71.9 (d, *J* = 11.5 Hz), 51.6 (s), 55.2 (s), 53.8 (s), 44.6 (s), 38.7 (s), 38.4 (s), 35.9 (s), 34.1 (s), 32.9 (s), 32.0 (s), 29.8 (s), 24.6 (s), 24.0 (d, *J* = 3.7 Hz), 23.74 (s), 23.70 (d, *J* = 5.6 Hz), 21.1 (s), 17.5 (s), 13.9 (s). ^{31}P NMR (242 MHz, $CDCl_3$) δ (ppm) 14.4 (s). HRMS calcd for $C_{34}H_{45}NaO_6PS^+$ $[M+Na]^+$, 635.2567; found, 635.2571.

^{31}P NMR, ^{1}H NMR and ^{13}C NMR Spectra for All Compounds

3



3



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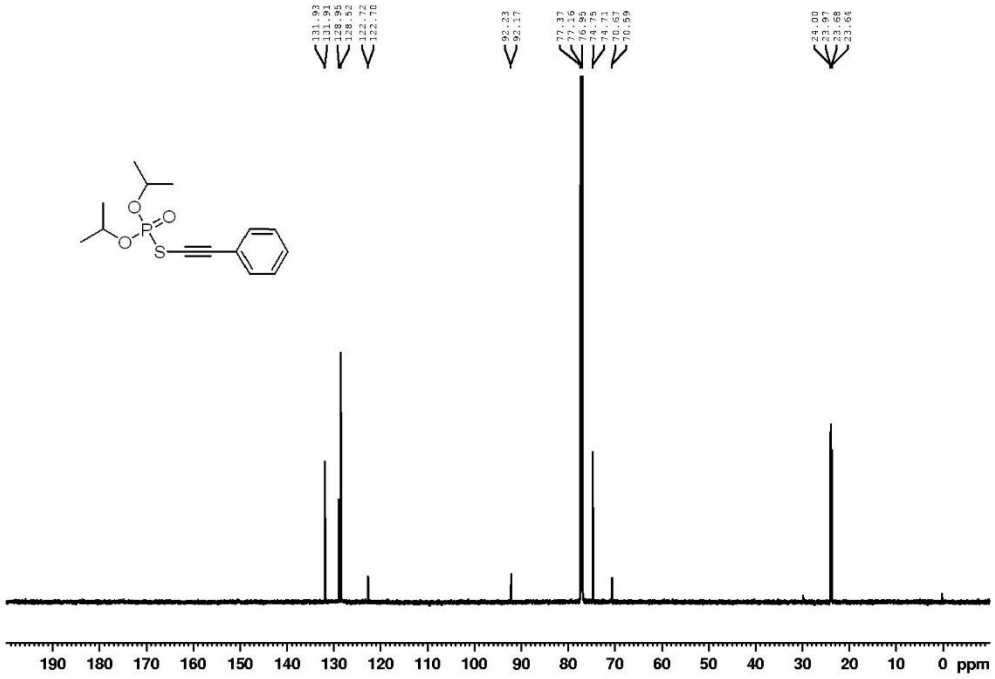
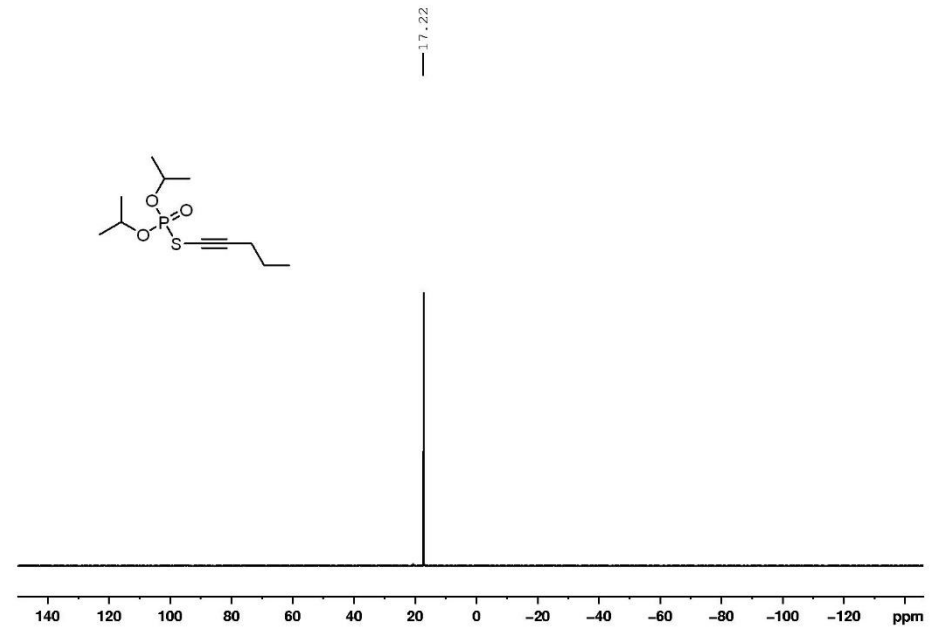
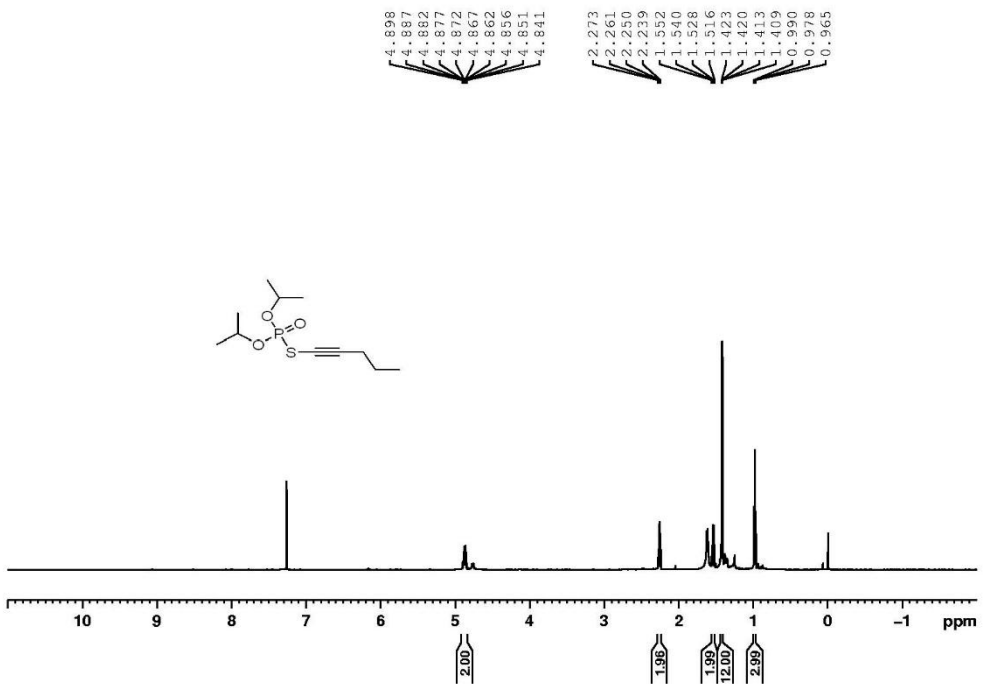

131.93
131.91
128.95
128.52
122.72
122.70
92.23
92.17
77.37
77.16
76.95
74.75
74.71
70.67
70.59
24.00
23.97
23.68
23.64
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

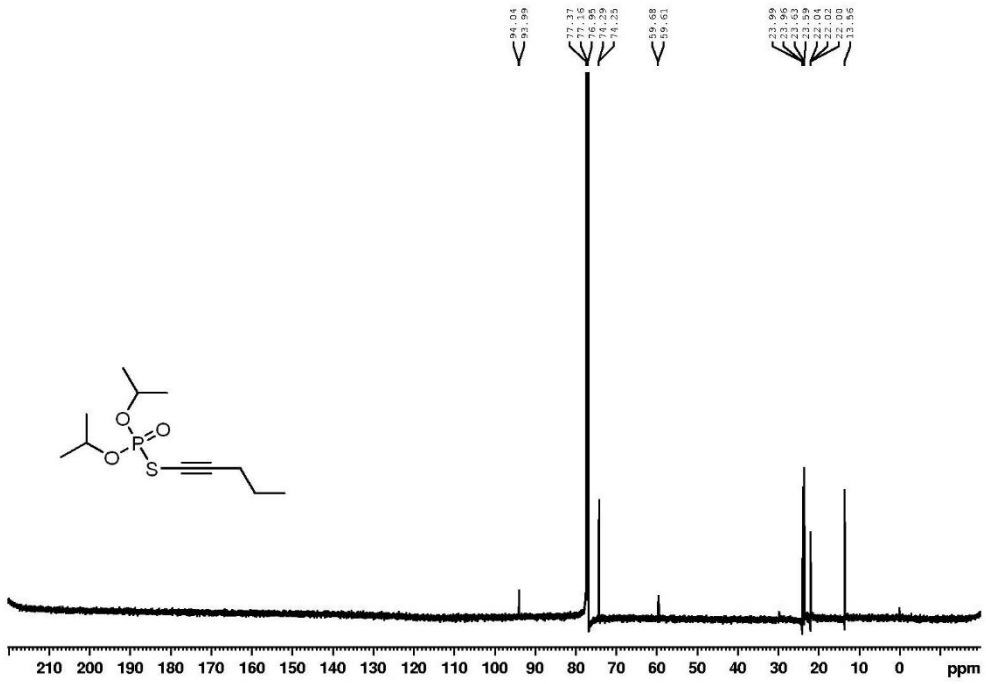
4


17.22
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

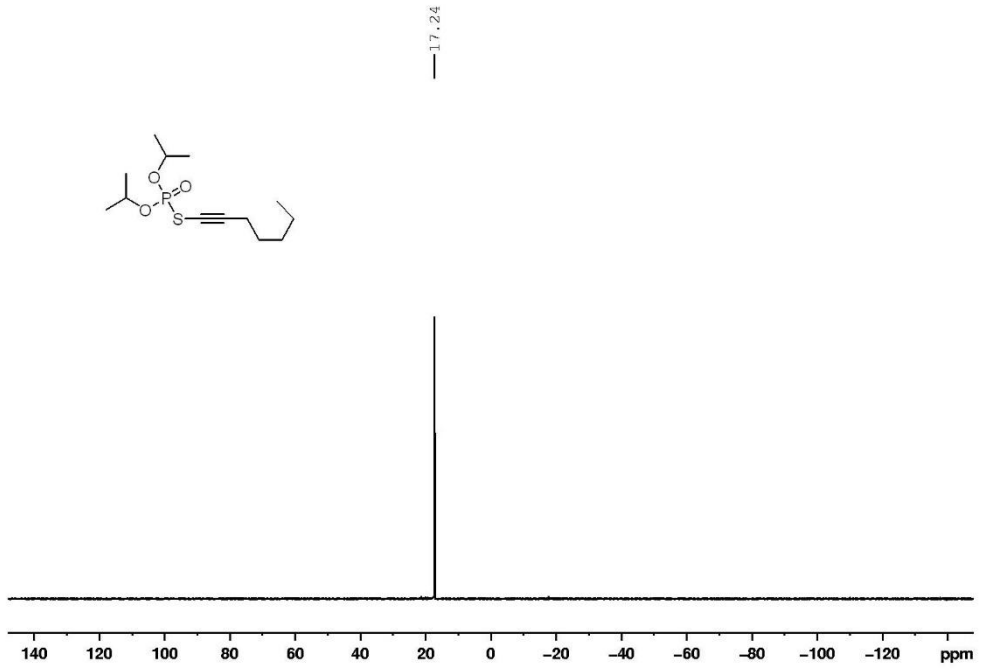
4


4.898
4.887
4.882
4.877
4.872
4.867
4.862
4.856
4.851
4.841
2.273
2.261
2.250
2.239
1.552
1.540
1.528
1.516
1.423
1.420
1.413
1.409
0.990
0.978
0.965
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
2.00
1.96
1.99
12.00
2.99

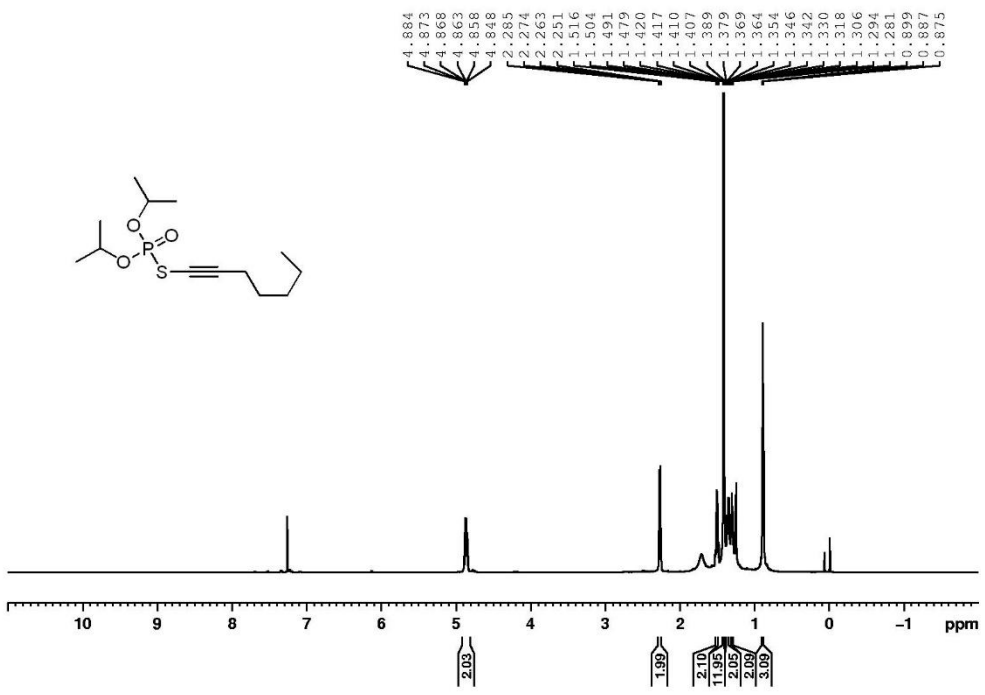
4


94.04
93.99
77.37
77.16
76.95
74.29
74.25
59.68
59.61
23.99
23.95
23.63
23.59
22.04
22.02
22.00
13.56
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

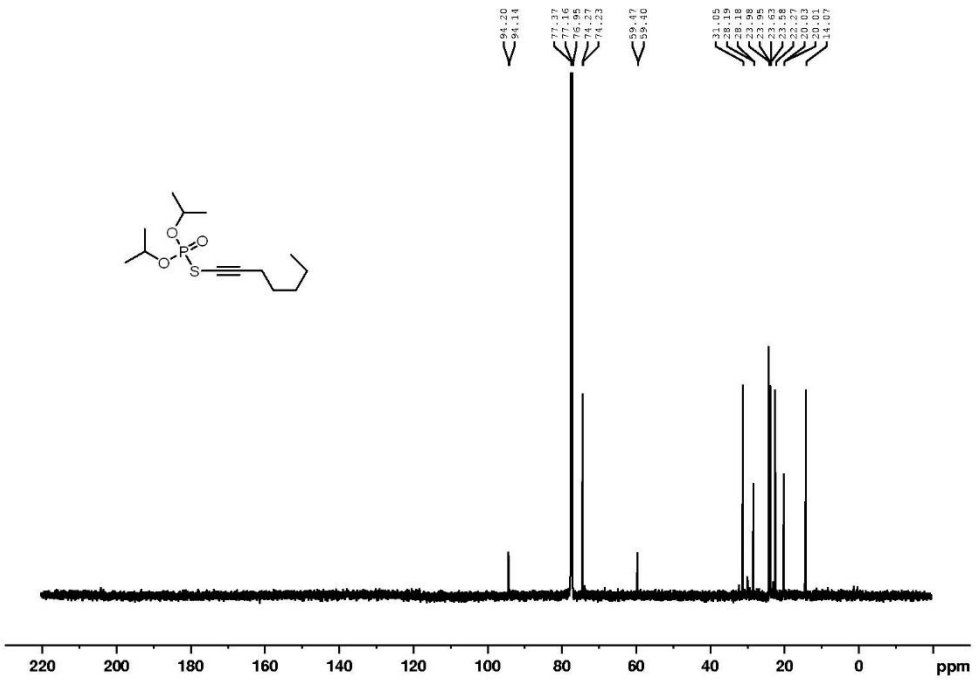
5


17.24
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

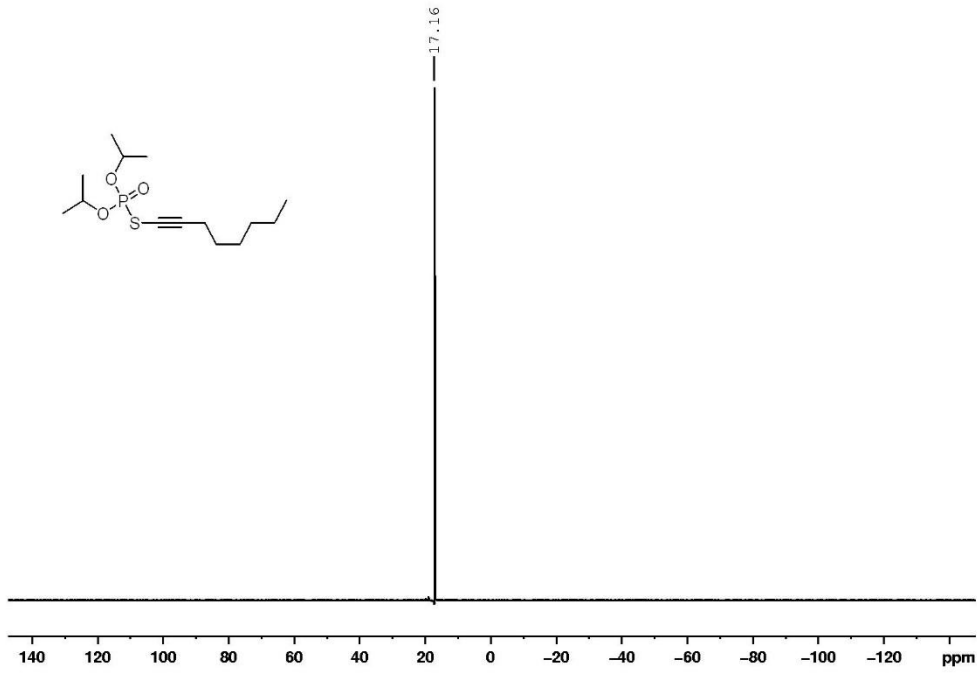
5


4.884
4.873
4.868
4.863
4.858
4.848
2.285
2.274
2.263
2.251
1.516
1.504
1.491
1.479
1.420
1.417
1.410
1.407
1.389
1.379
1.369
1.364
1.354
1.346
1.342
1.330
1.318
1.306
1.294
1.281
0.899
0.887
0.875
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
2.03
1.99
2.10
11.95
2.05
2.09
3.09

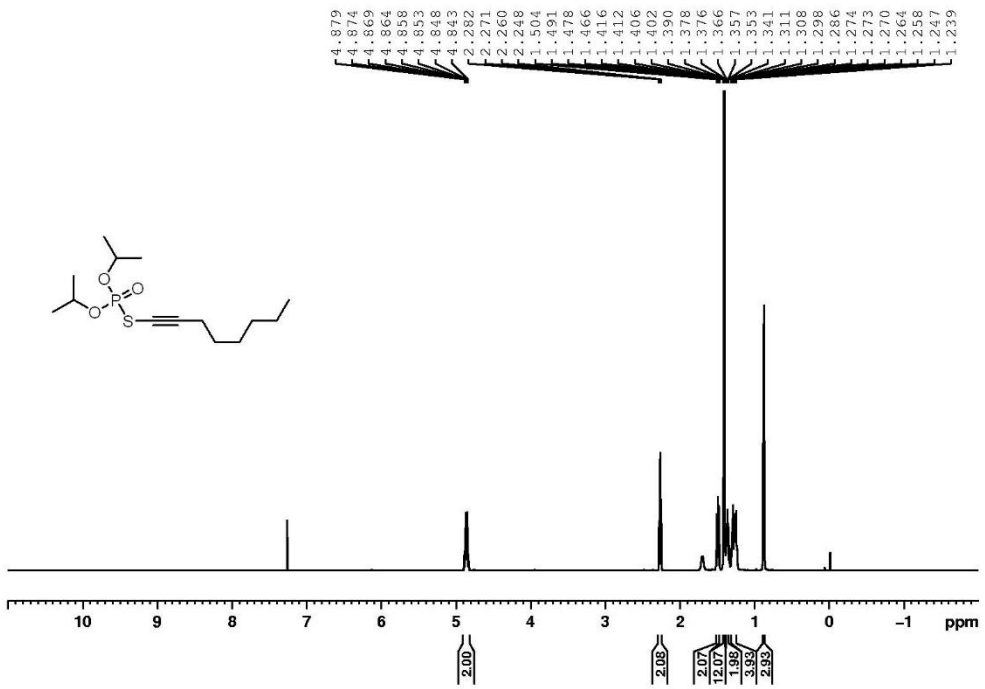
5


94.20
94.14
77.37
77.16
76.95
74.27
74.23
59.47
59.40
31.05
28.19
28.18
23.98
23.85
23.63
23.58
22.27
20.03
20.01
14.07
220
200
180
160
140
120
100
80
60
40
20
0
ppm

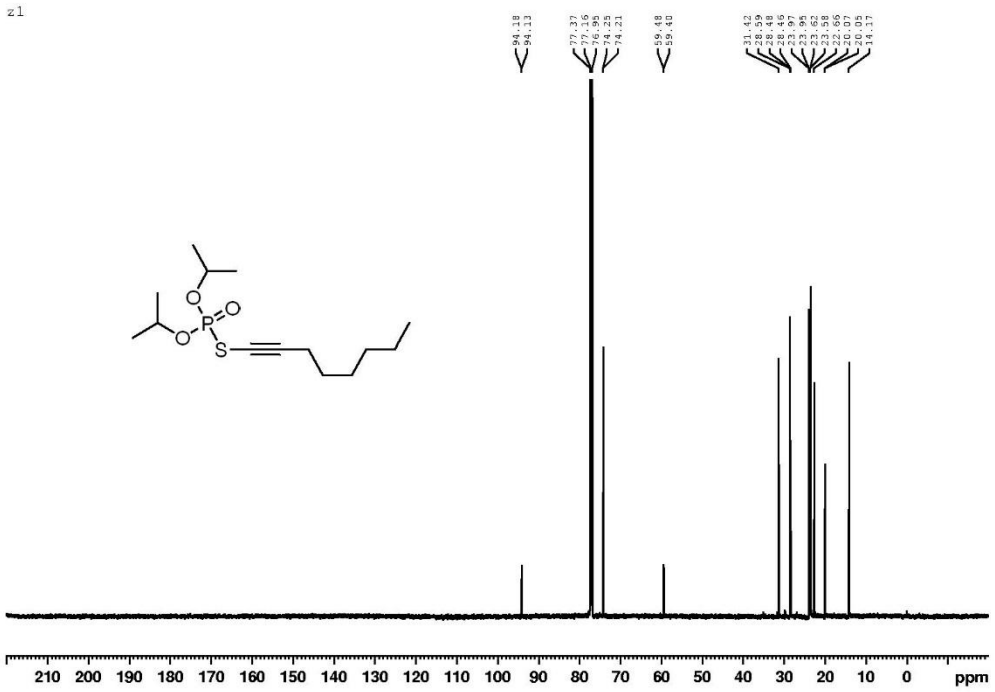
6


17.16
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

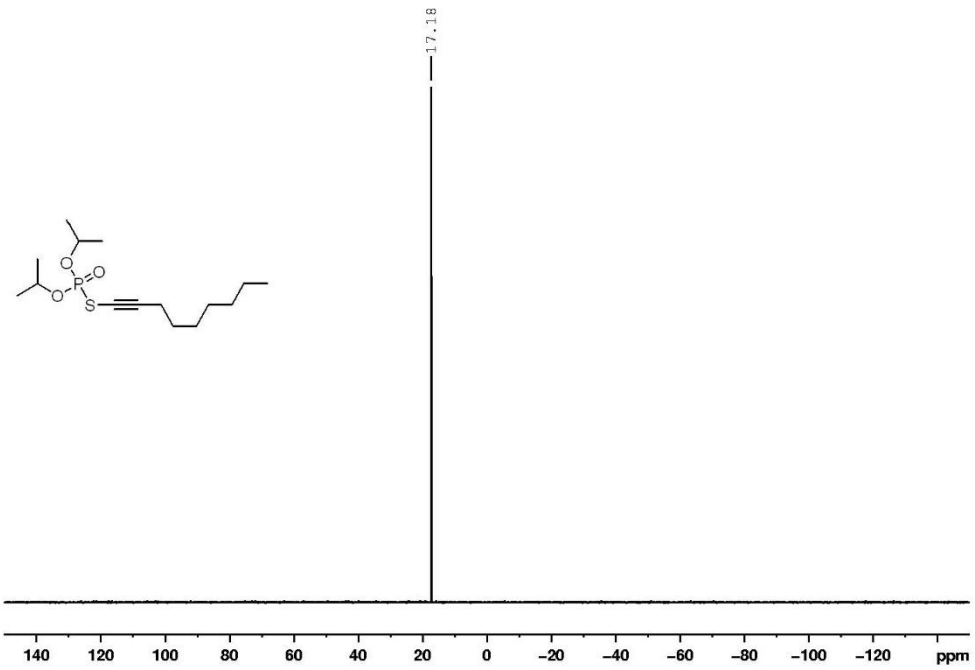
6


4.879
4.874
4.869
4.864
4.858
4.853
4.848
4.843
2.282
2.271
2.260
2.248
1.504
1.491
1.478
1.466
1.416
1.412
1.406
1.402
1.390
1.378
1.376
1.366
1.357
1.353
1.341
1.311
1.308
1.298
1.286
1.274
1.273
1.270
1.264
1.258
1.247
1.239
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
2.00
2.06
2.07
12.07
1.98
3.93
2.93

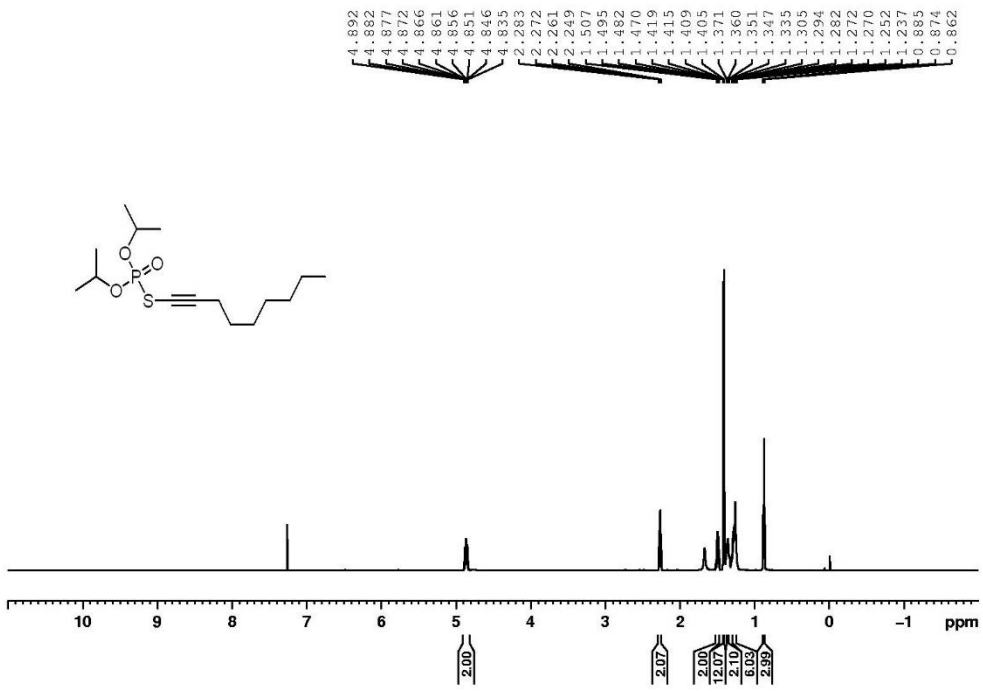
6


z1
94.18
94.13
77.37
77.16
76.95
74.25
74.21
59.48
59.40
31.42
28.59
28.48
28.46
23.97
23.94
23.82
23.58
22.66
20.07
20.05
14.17
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

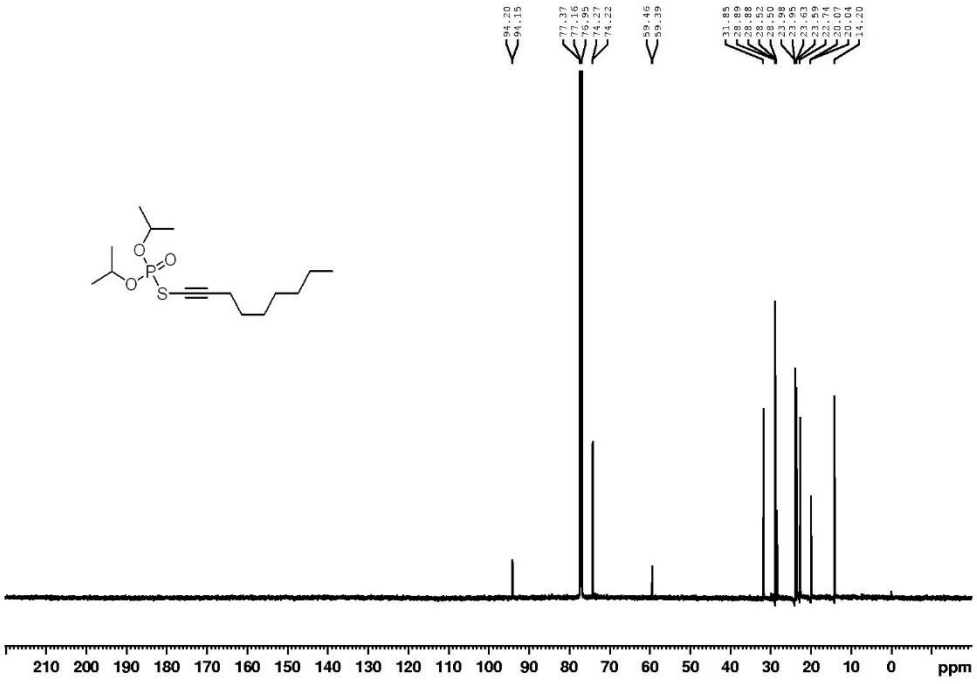
7


17.18
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

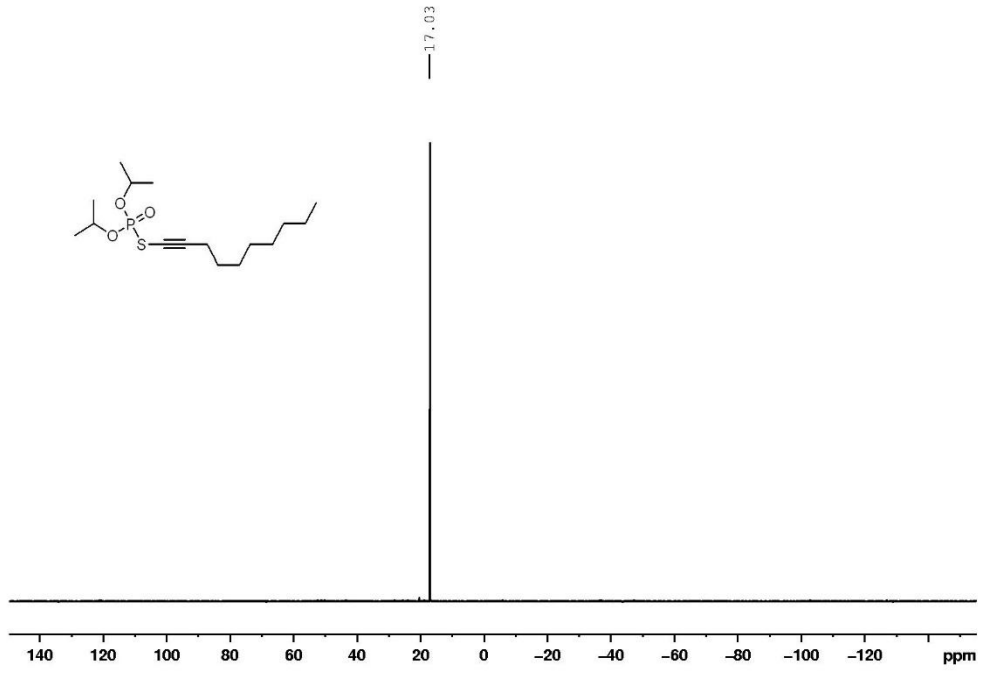
7


4.892
4.882
4.877
4.872
4.866
4.861
4.856
4.851
4.846
4.835
2.283
2.272
2.261
2.249
1.507
1.495
1.482
1.470
1.419
1.415
1.409
1.405
1.371
1.360
1.351
1.347
1.335
1.305
1.294
1.282
1.272
1.270
1.252
1.237
0.885
0.874
0.862
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
2.00
2.07
2.00
12.07
2.10
6.03
2.99

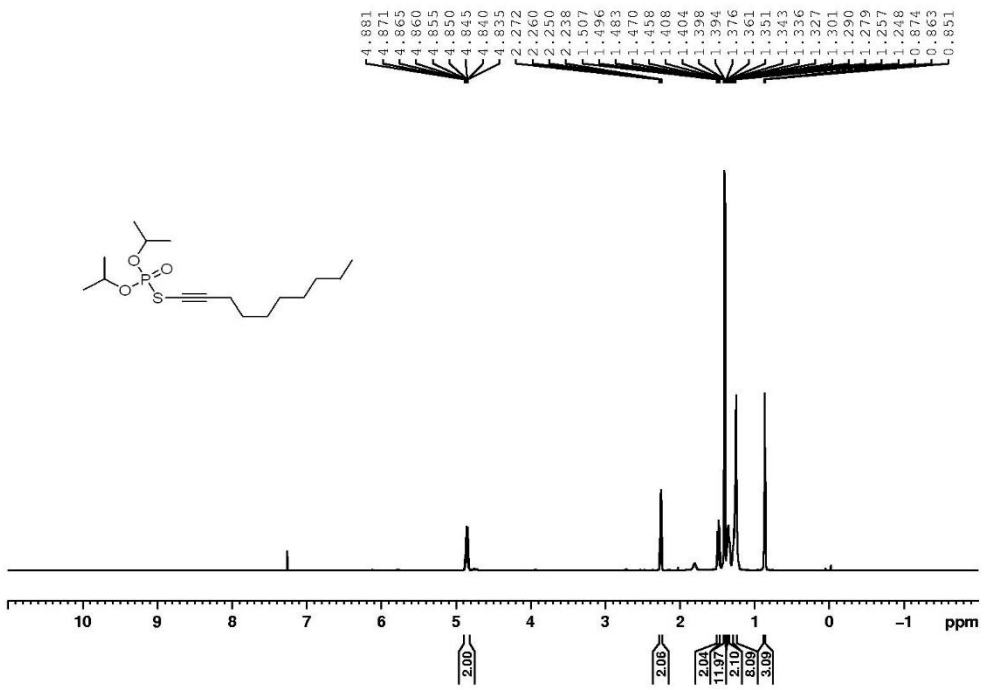
7


94.20
94.15
77.37
77.16
76.95
74.27
74.22
59.46
59.39
31.85
28.89
28.88
28.52
28.50
23.98
23.95
23.63
23.58
22.74
20.07
20.04
14.20
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

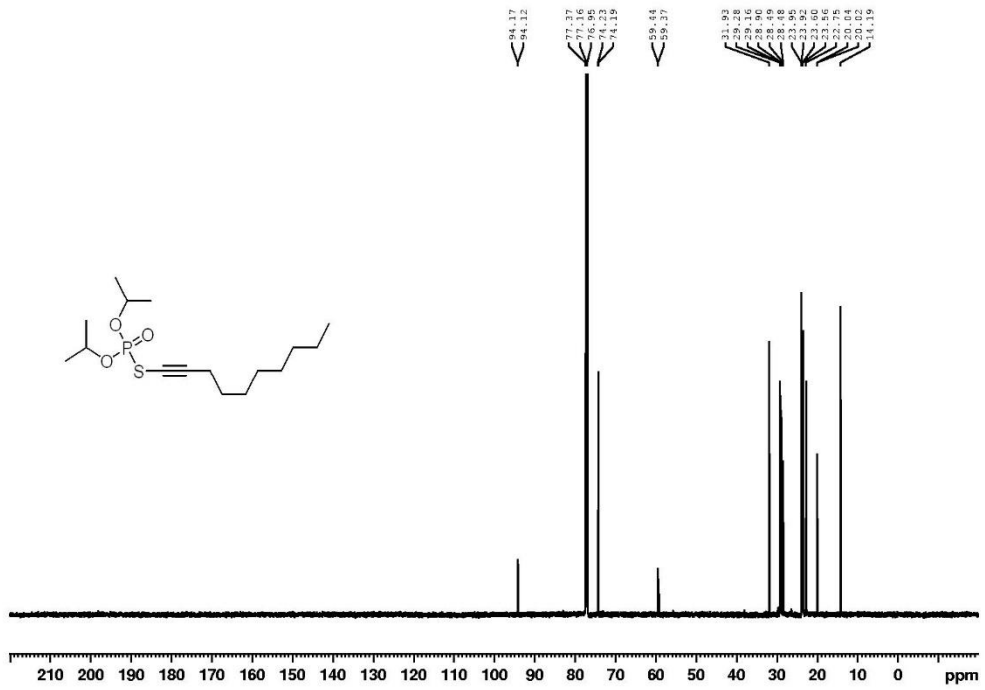
8


17.03
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

8


4.881
4.871
4.865
4.860
4.855
4.850
4.845
4.840
4.835
2.272
2.260
2.250
2.238
1.507
1.496
1.483
1.470
1.458
1.408
1.404
1.398
1.394
1.376
1.361
1.351
1.343
1.336
1.327
1.301
1.290
1.279
1.257
1.248
0.874
0.863
0.851
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
2.00
2.06
2.04
11.97
2.10
8.09
3.09

8


94.17
94.12
77.37
77.16
76.95
74.33
74.19
59.44
59.37
31.93
29.28
29.16
28.90
28.49
28.48
28.45
23.92
23.60
23.56
22.75
20.04
20.02
14.19
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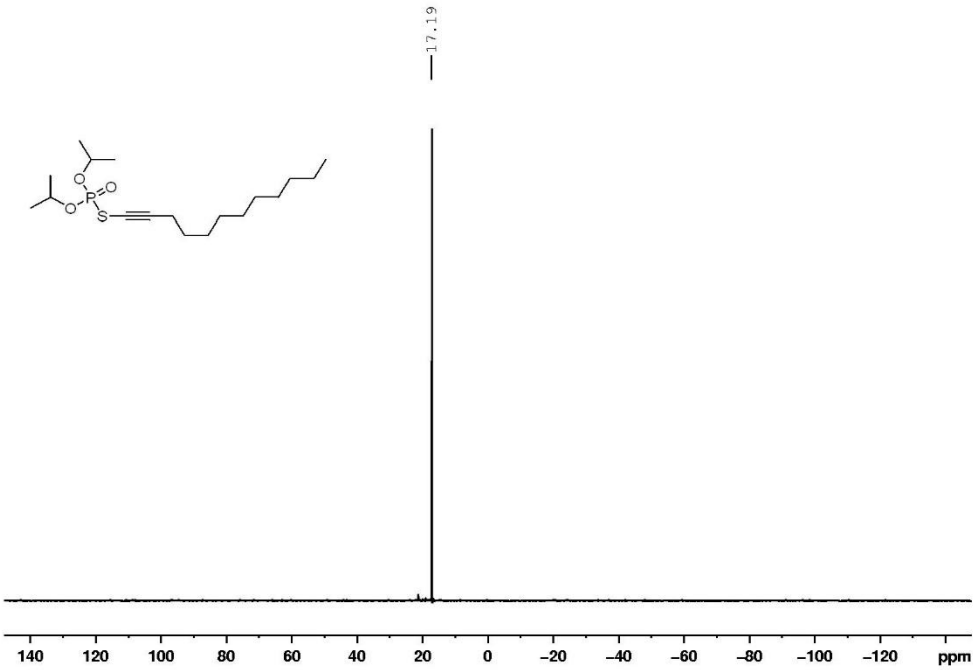
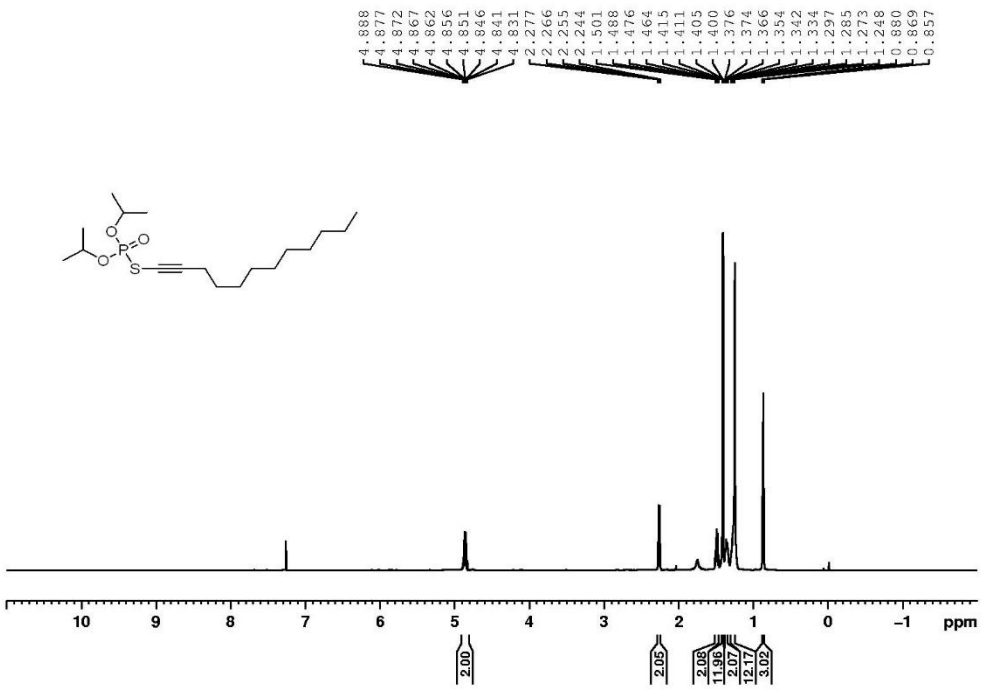
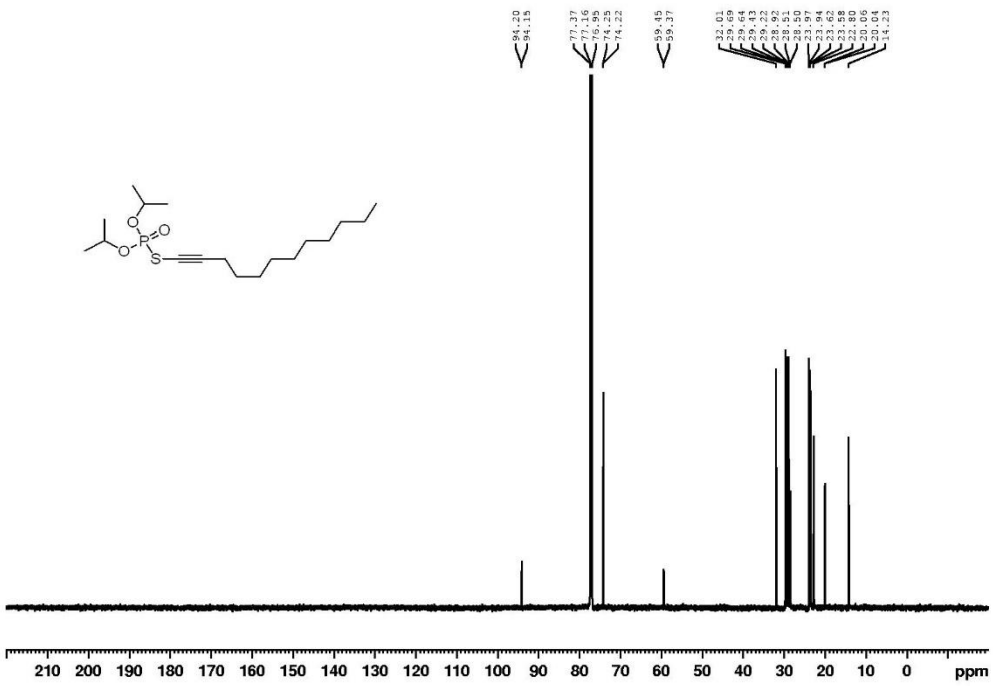
9


17.19
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

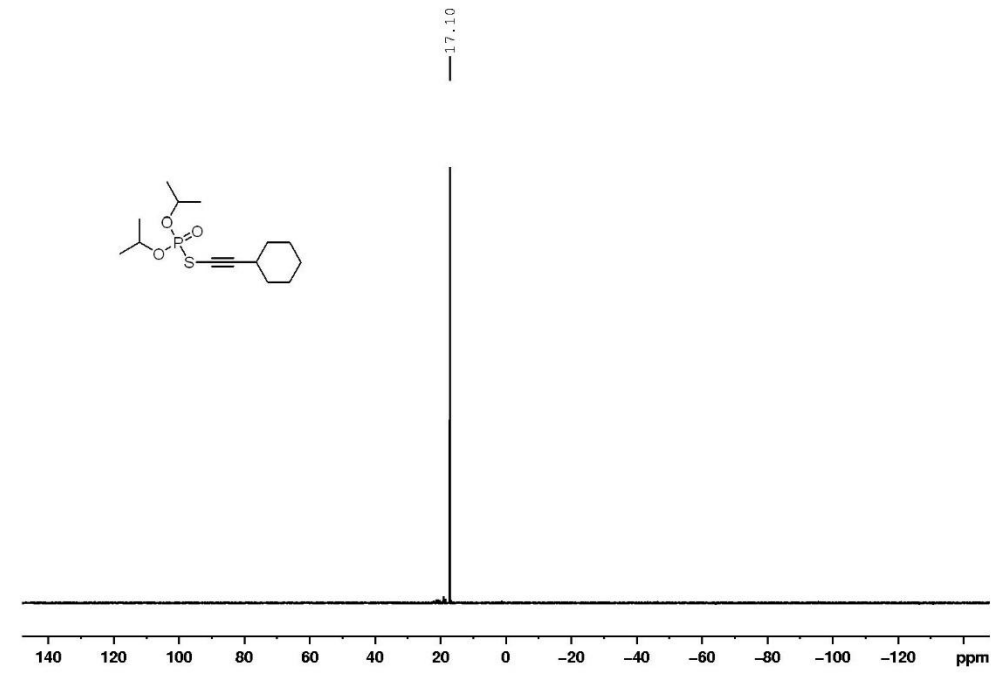
9


4.888
4.877
4.872
4.867
4.862
4.856
4.851
4.846
4.841
4.831
2.277
2.266
2.255
2.244
1.501
1.488
1.476
1.464
1.415
1.411
1.405
1.400
1.376
1.374
1.366
1.354
1.342
1.334
1.297
1.285
1.273
1.248
0.880
0.869
0.857
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
2.00
2.05
2.08
11.96
2.07
12.17
3.02

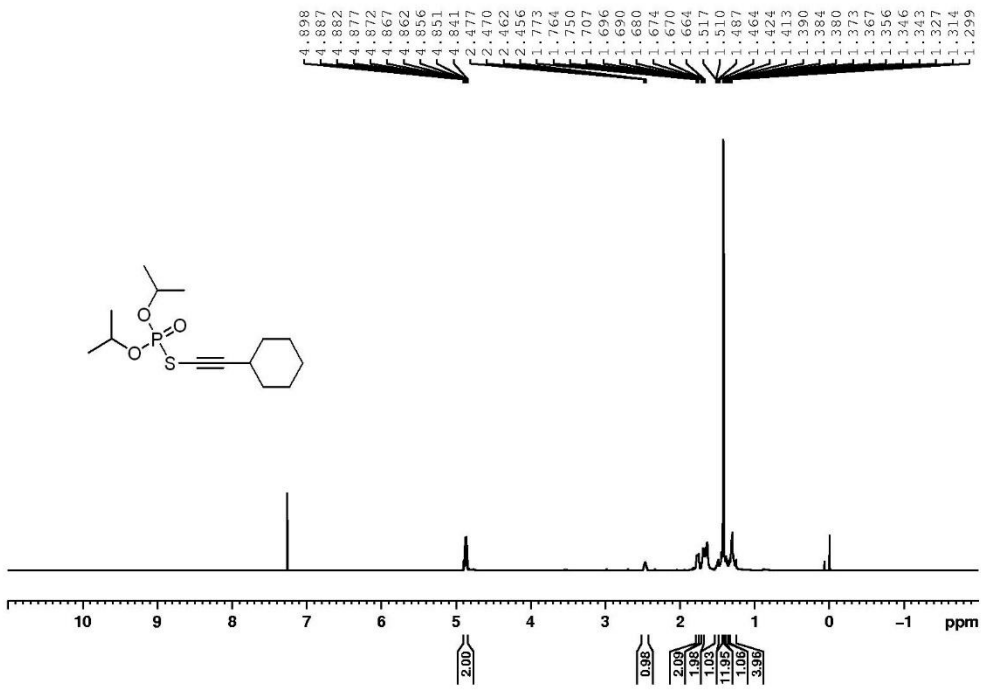
9


94.20
94.15
77.37
77.16
76.95
74.25
74.22
59.45
59.37
32.01
31.68
29.64
29.43
29.22
28.92
28.51
28.50
23.97
23.94
23.62
23.58
22.80
20.06
20.04
14.23
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

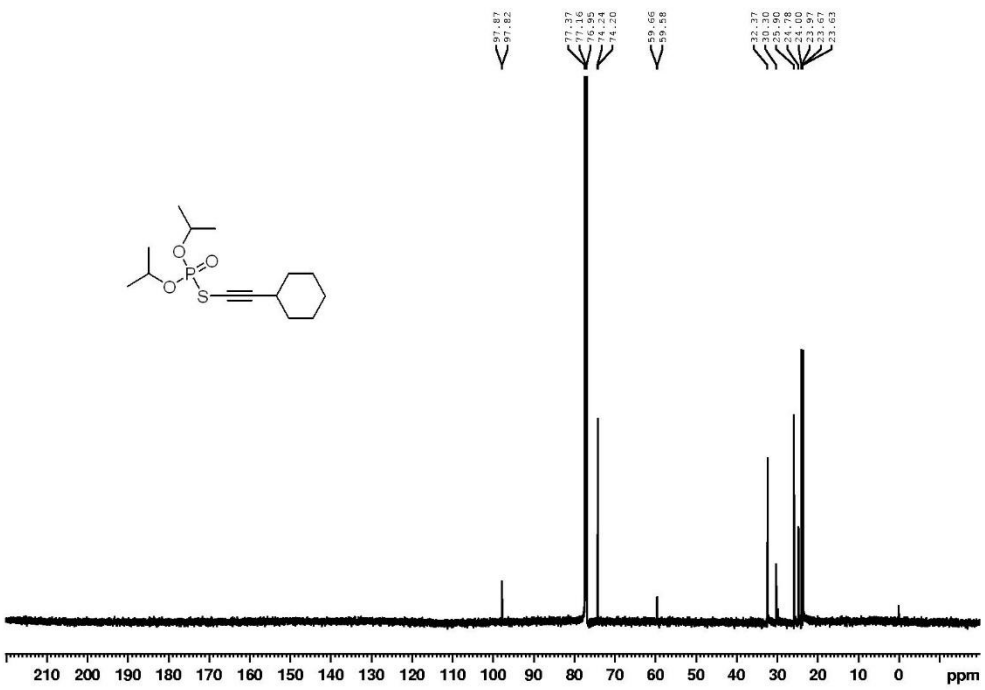
10


17.10
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

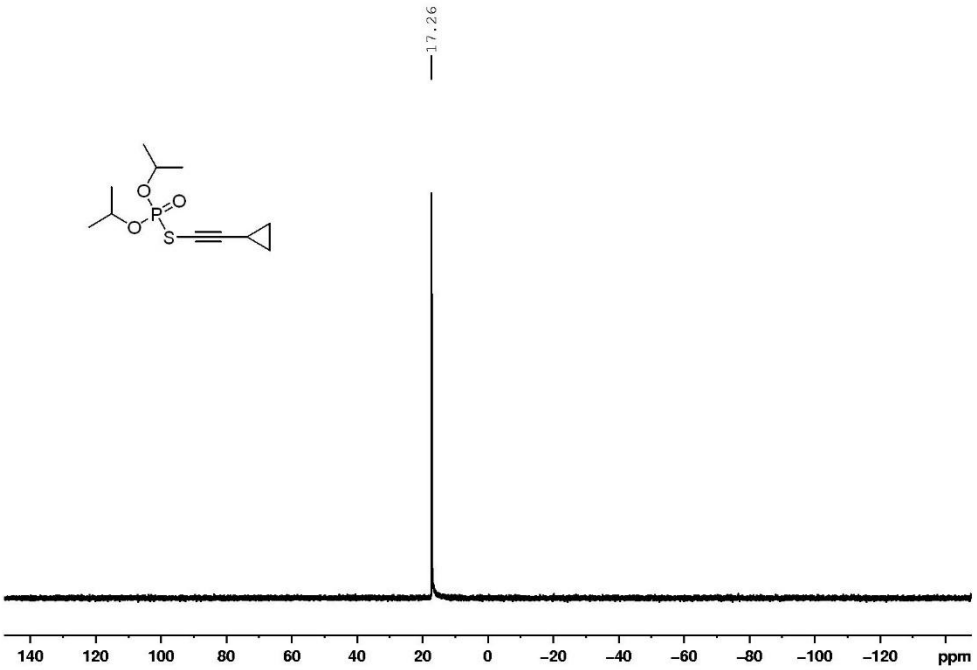
10


4.898
4.887
4.882
4.877
4.872
4.867
4.862
4.856
4.851
4.841
2.477
2.470
2.462
2.456
1.773
1.764
1.750
1.707
1.696
1.690
1.680
1.674
1.670
1.664
1.517
1.510
1.487
1.464
1.424
1.413
1.390
1.384
1.380
1.373
1.367
1.356
1.346
1.343
1.327
1.314
1.299
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
2.00
0.96
2.00
1.98
1.03
11.95
1.06
3.96

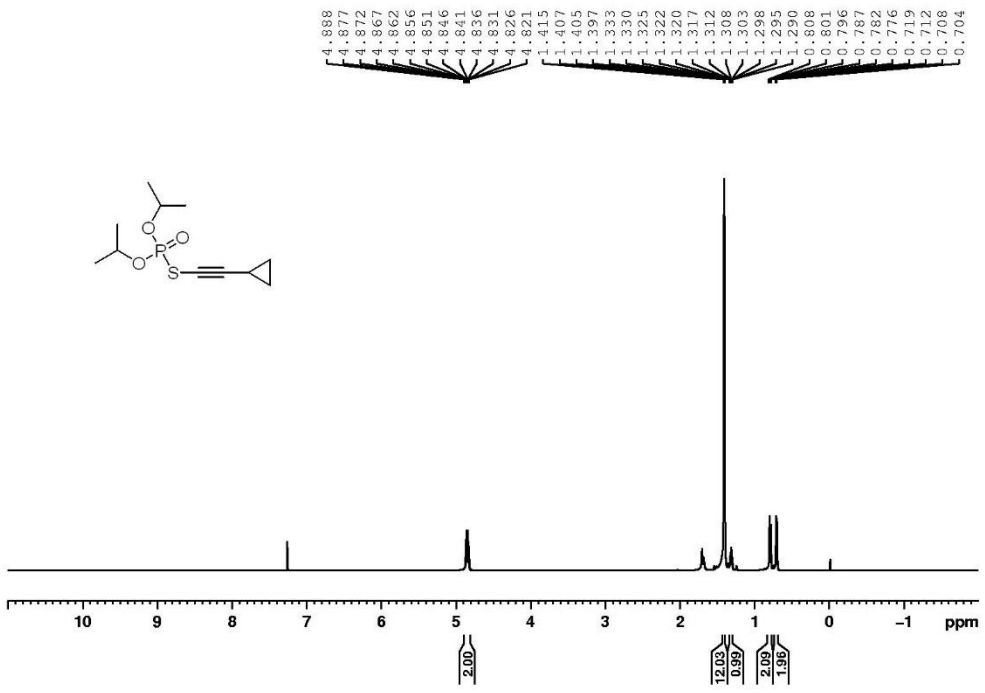
10


97.87
97.82
77.37
77.16
76.95
74.24
74.20
59.66
59.58
32.37
30.30
25.80
24.78
24.00
23.97
23.67
23.63
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

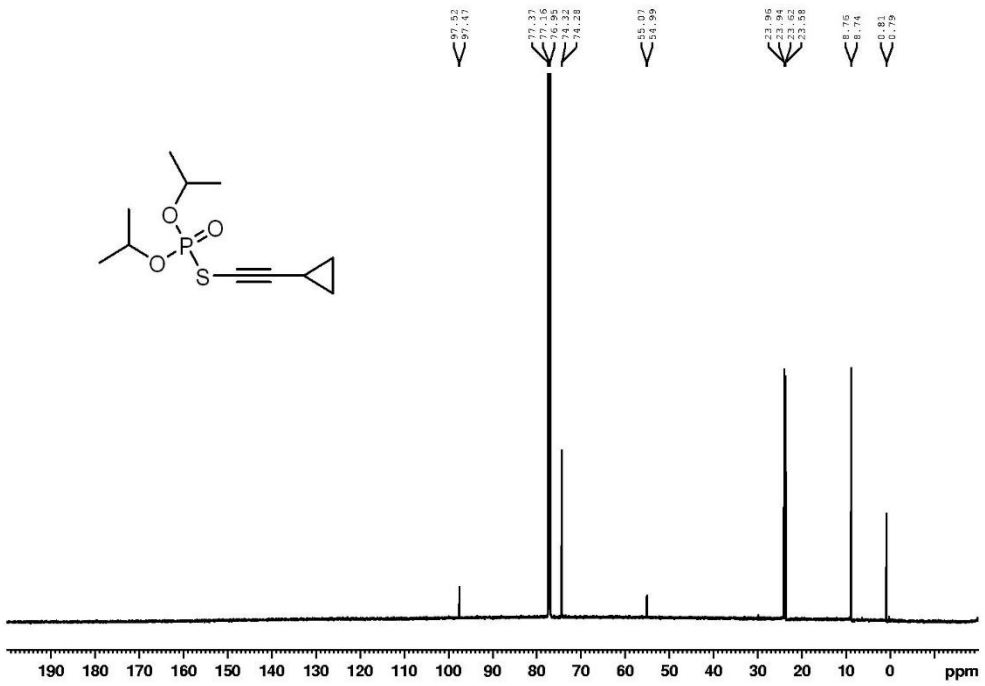
11


17.26
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

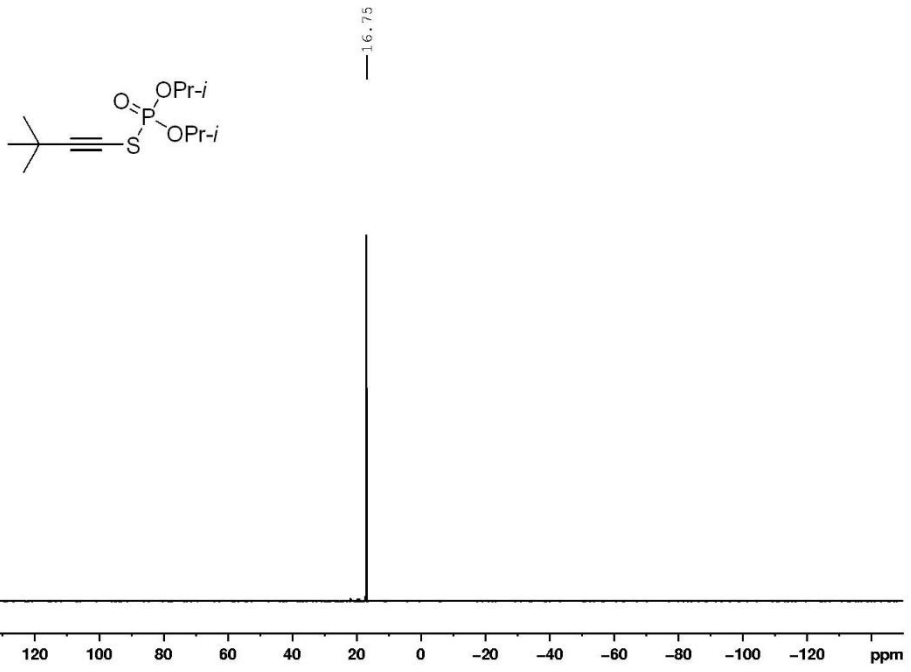
11


4.888
4.877
4.872
4.867
4.862
4.856
4.851
4.846
4.841
4.836
4.831
4.826
4.821
1.415
1.407
1.405
1.397
1.333
1.330
1.325
1.322
1.320
1.317
1.312
1.308
1.303
1.298
1.295
1.290
0.808
0.801
0.796
0.787
0.782
0.776
0.719
0.712
0.708
0.704
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
2.00
12.03
0.99
2.09
1.96

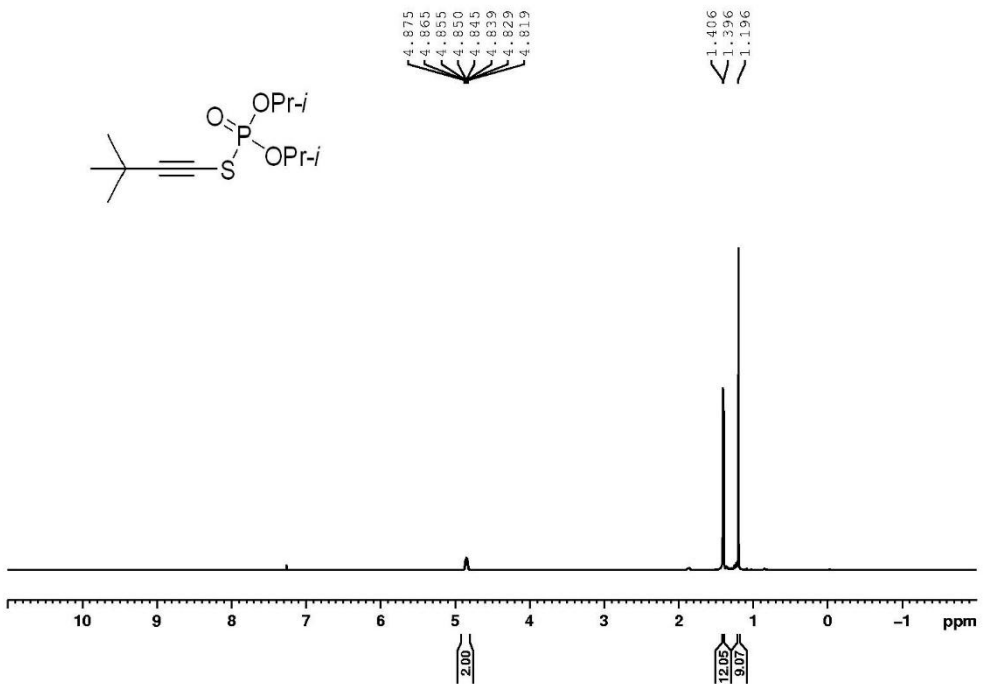
11


97.52
97.47
77.37
77.16
76.95
74.33
74.28
55.07
54.99
23.96
23.94
23.63
23.58
8.76
8.74
0.81
0.79
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

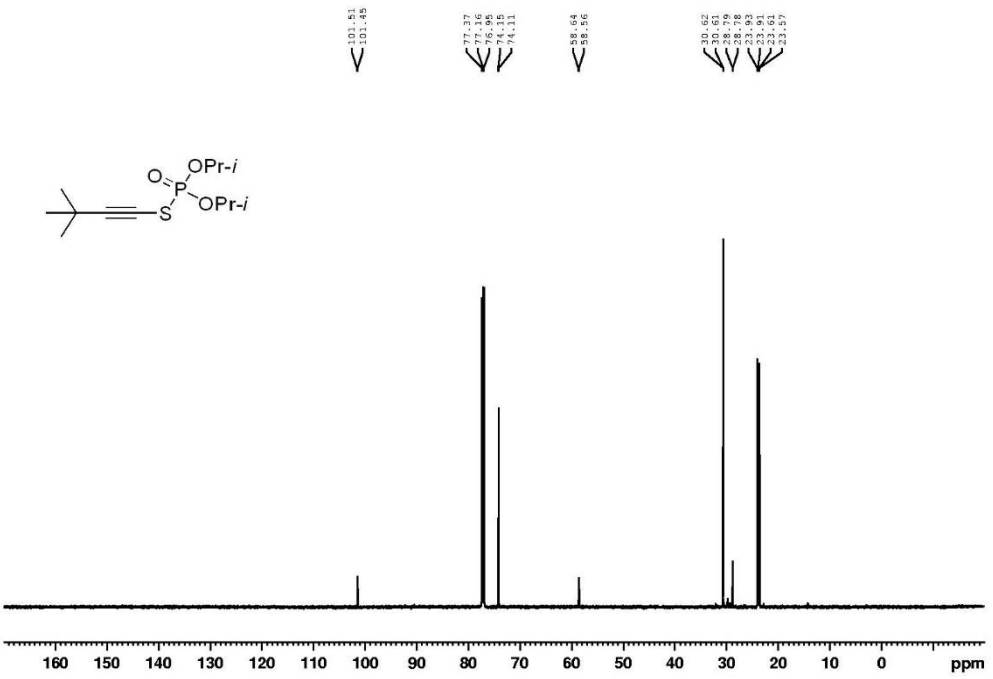
12


16.75
OPr-i
OPr-i
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

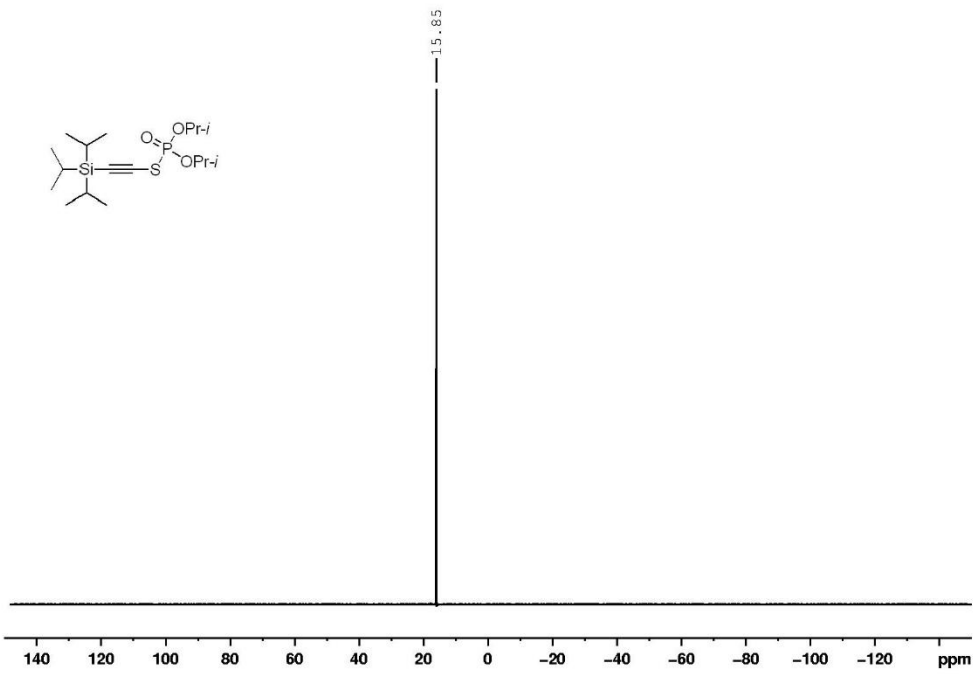
12


4.875
4.865
4.855
4.850
4.845
4.839
4.829
4.819
1.406
1.396
1.196
OPr-i
OPr-i
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
2.00
12.05
9.07

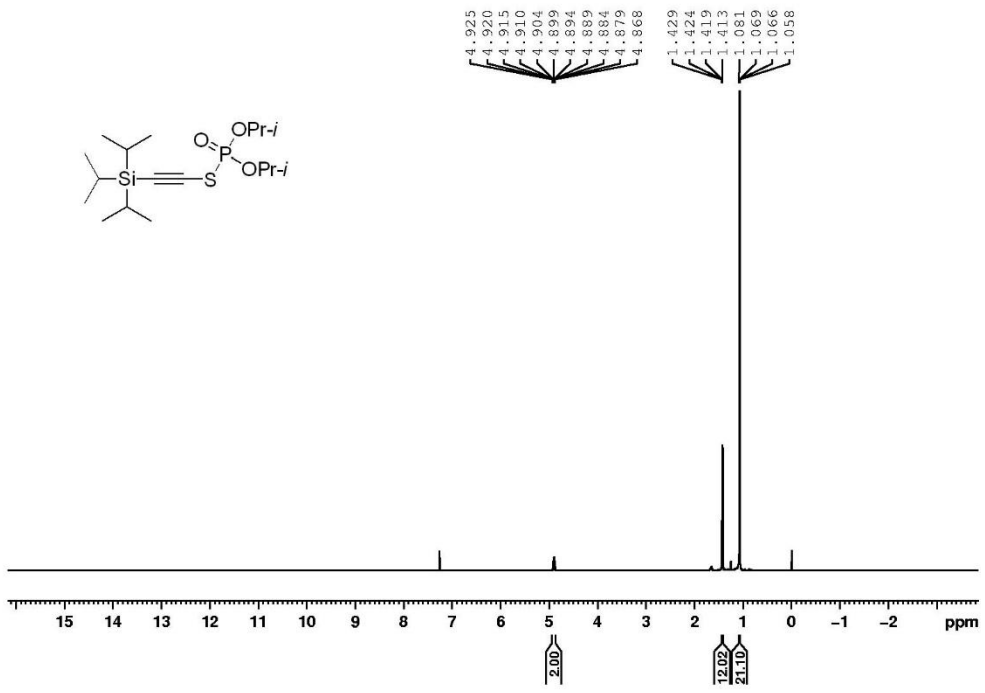
12


101.51
101.45
77.37
77.16
76.95
74.15
74.11
58.64
58.56
30.62
30.56
28.79
28.78
23.93
23.91
23.63
23.57
OPr-i
OPr-i
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

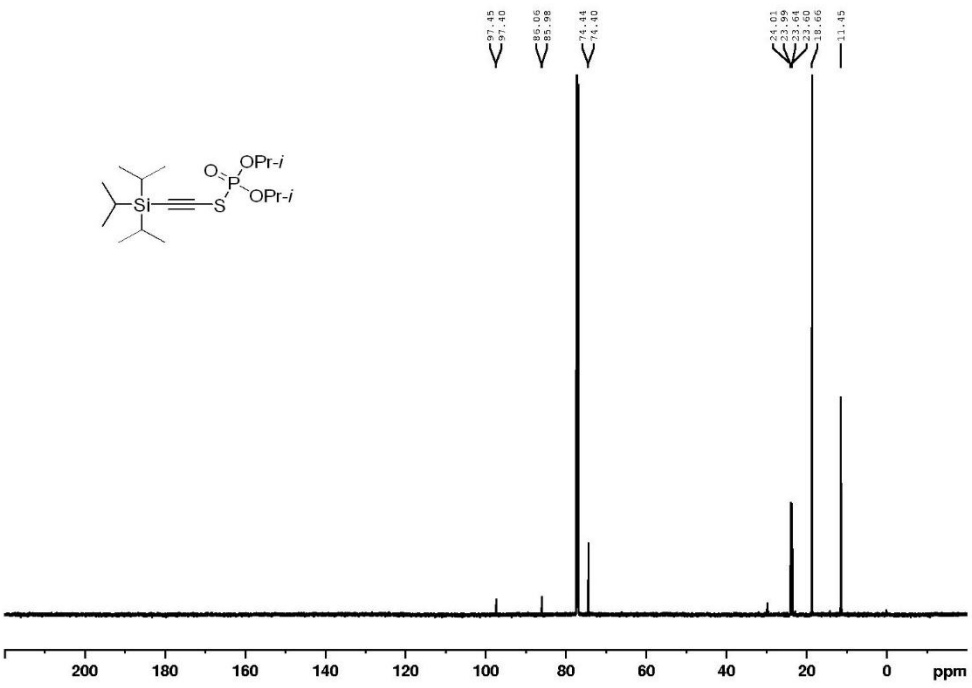
13


15.85
OPr-i
OPr-i
Si
S
P
O
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

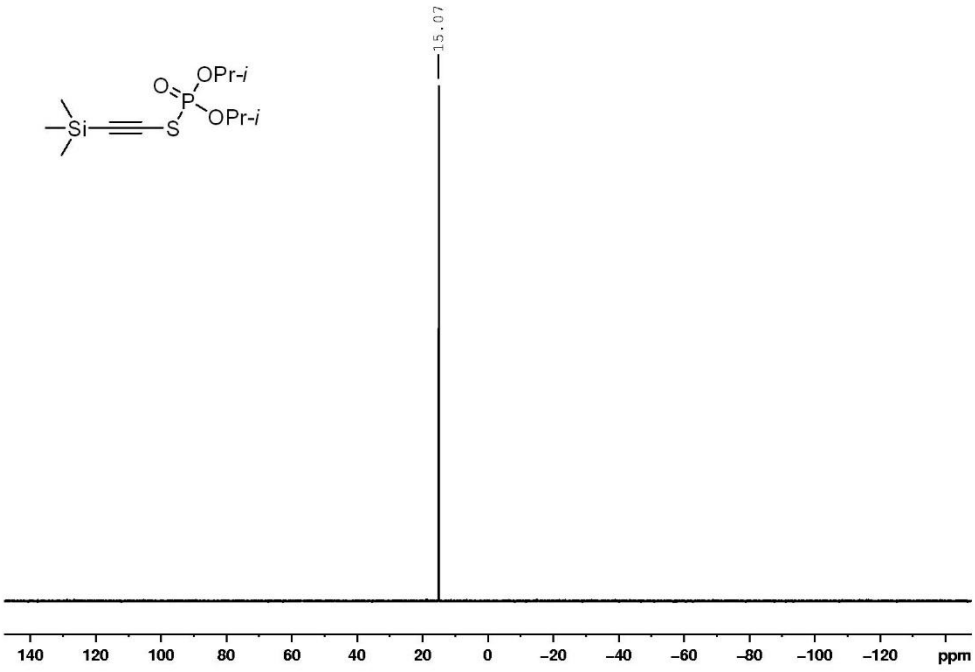
13


4.925
4.920
4.915
4.910
4.904
4.899
4.894
4.889
4.884
4.879
4.868
1.429
1.424
1.419
1.413
1.081
1.069
1.066
1.058
OPr-i
OPr-i
Si
S
P
O
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
ppm
2.00
12.02
21.10

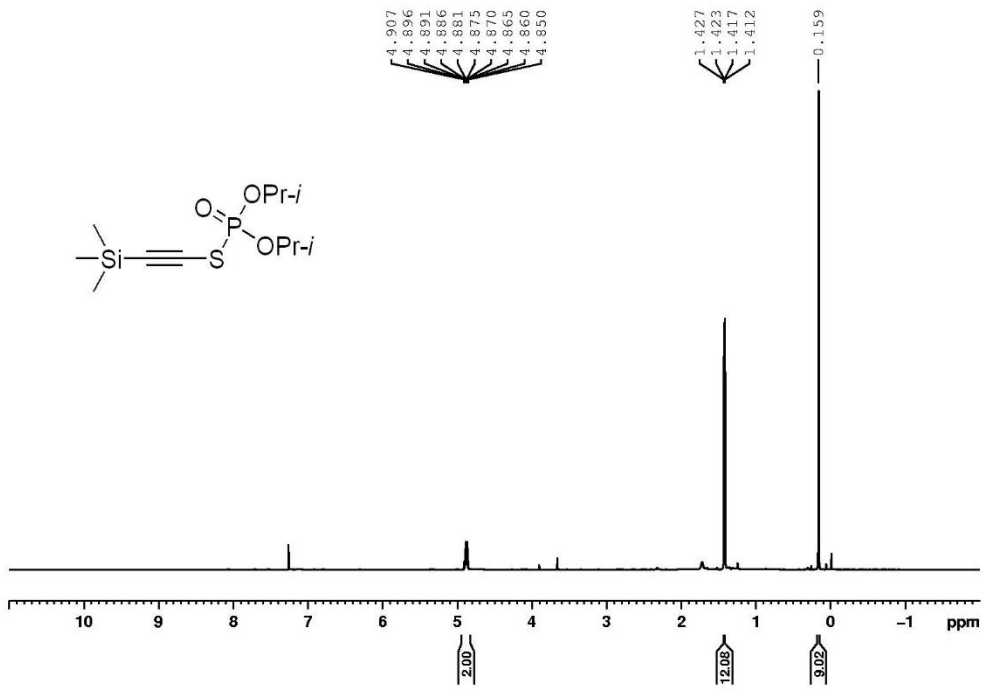
13


97.45
97.40
86.06
85.98
74.44
74.40
24.01
23.99
23.64
23.60
18.66
11.45
OPr-*i*
OPr-*i*
Si
S
P
O
200
180
160
140
120
100
80
60
40
20
0
ppm

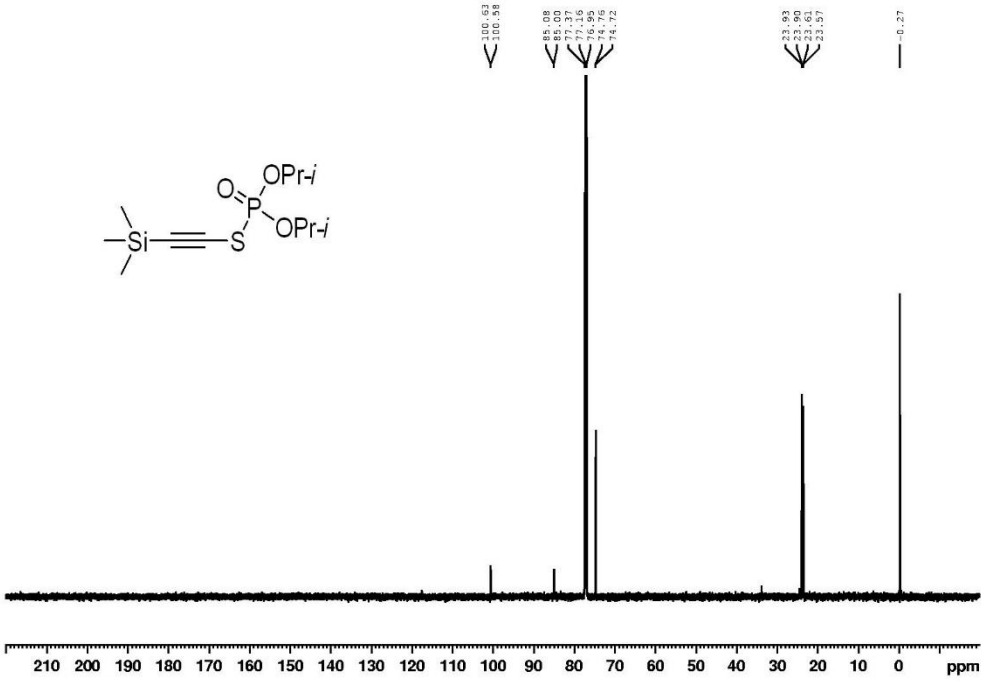
14


15.07
OPr-*i*
OPr-*i*
Si
S
P
O
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

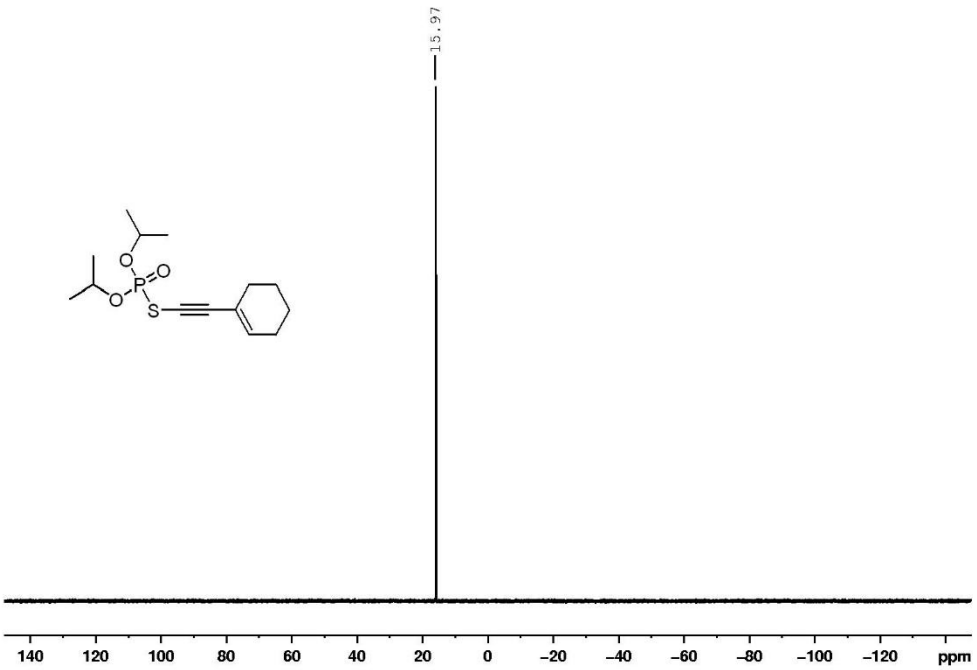
14


4.907
4.896
4.891
4.886
4.881
4.875
4.870
4.865
4.860
4.850
1.427
1.423
1.417
1.412
0.159
OPr-i
OPr-i
Si
S
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
2.00
12.08
9.02

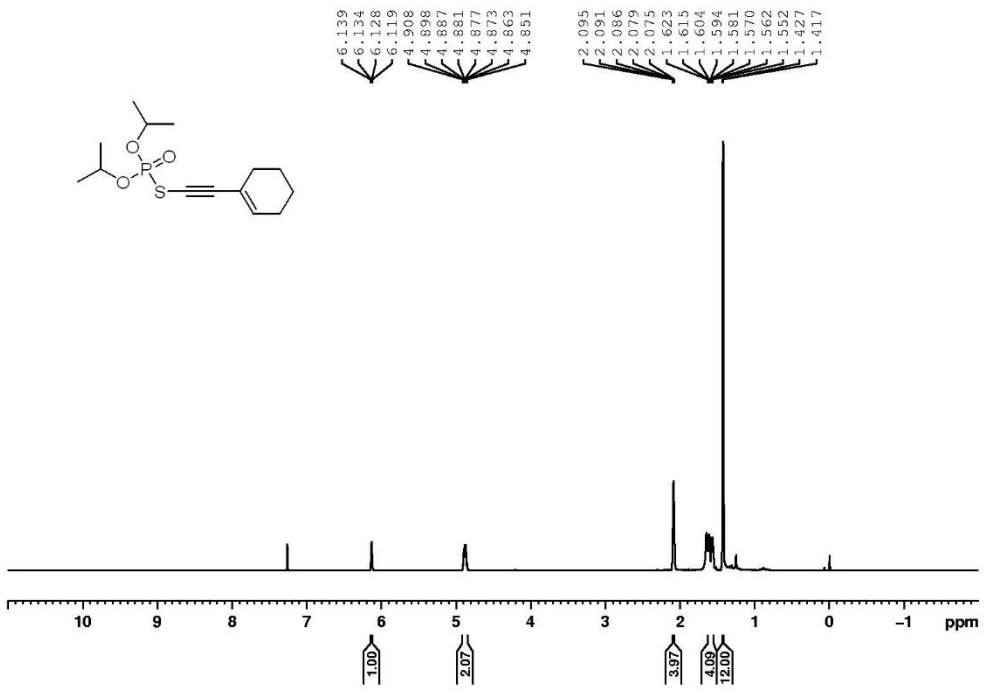
14


100.63
100.58
85.08
85.00
77.37
77.16
76.95
74.76
74.72
23.93
23.90
23.61
23.57
-0.27
OPr-i
OPr-i
Si
S
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

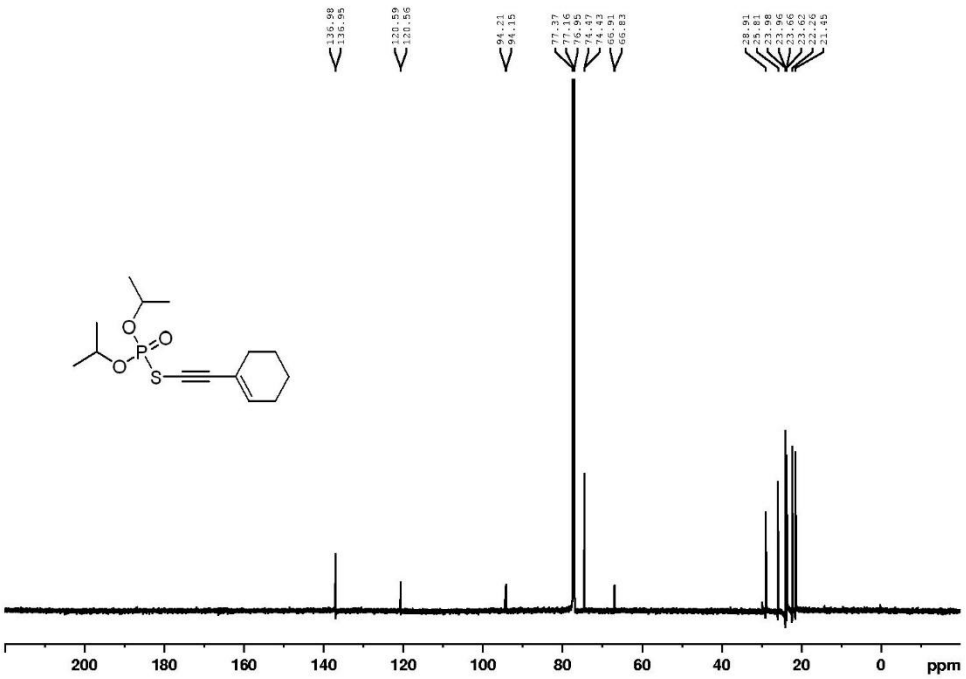
15


15.97
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

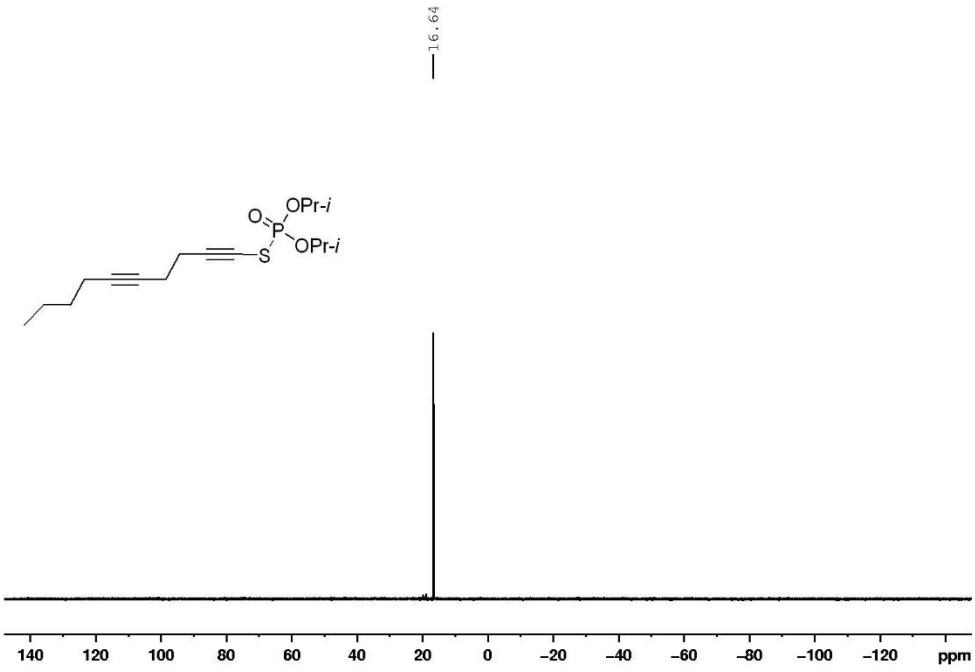
15


6.139
6.134
6.128
6.119
4.908
4.898
4.887
4.881
4.877
4.873
4.863
4.851
2.095
2.091
2.086
2.079
2.075
1.623
1.615
1.604
1.594
1.581
1.570
1.562
1.552
1.427
1.417
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
1.00
2.07
3.97
4.09
12.00

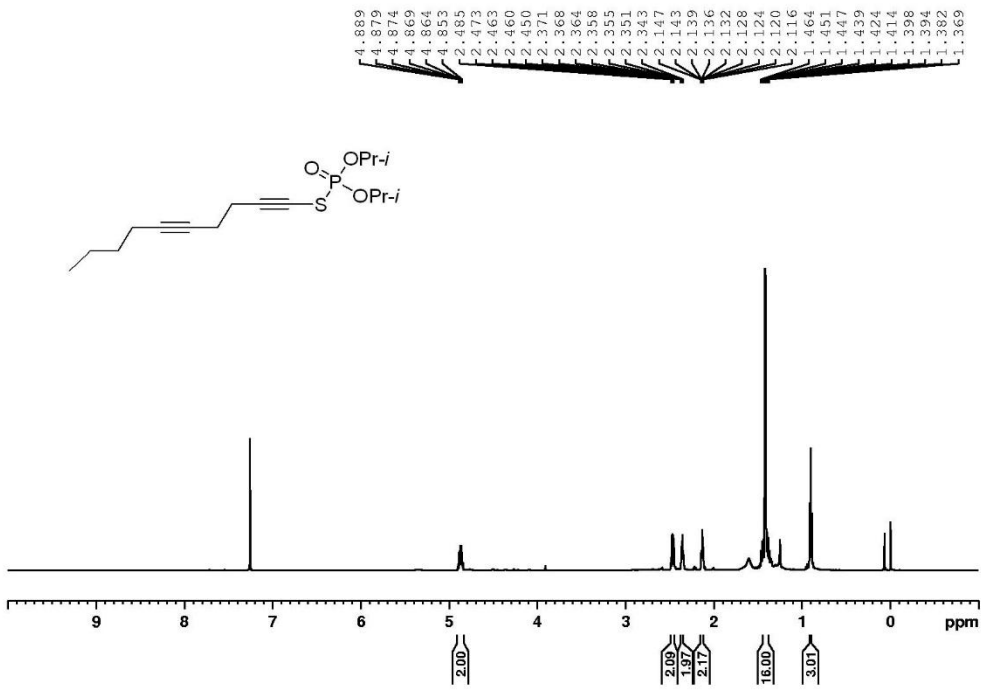
15


136.98
136.95
120.59
120.56
94.21
94.15
77.37
77.16
76.95
74.47
74.43
66.91
66.83
28.91
25.81
21.98
23.96
23.66
23.62
22.26
21.45
200
180
160
140
120
100
80
60
40
20
0
ppm

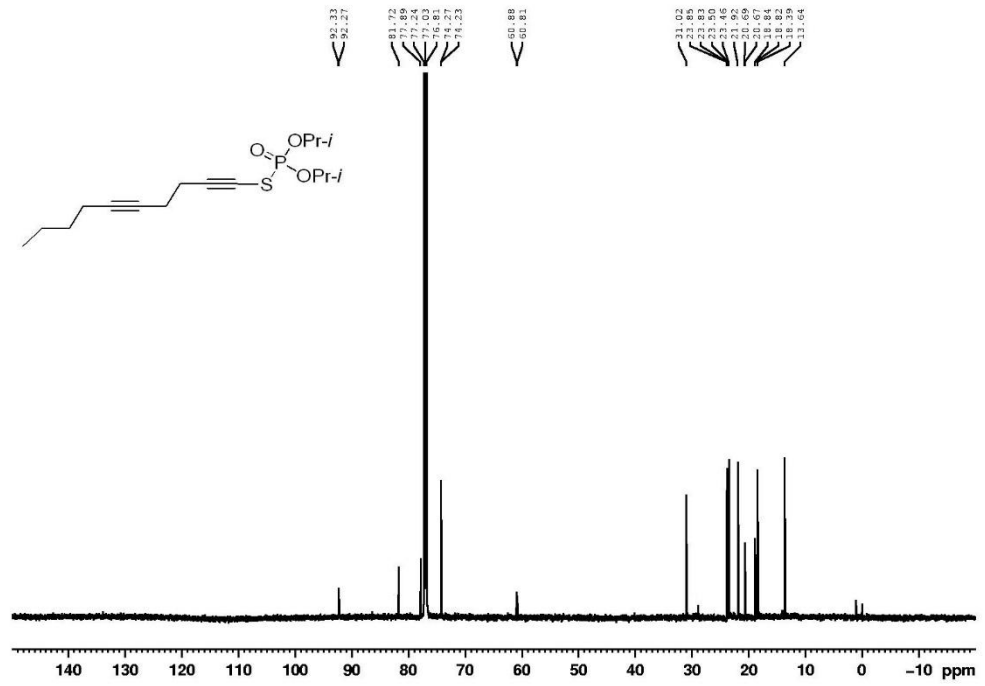
16


16.64
OPr-i
OPr-i
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

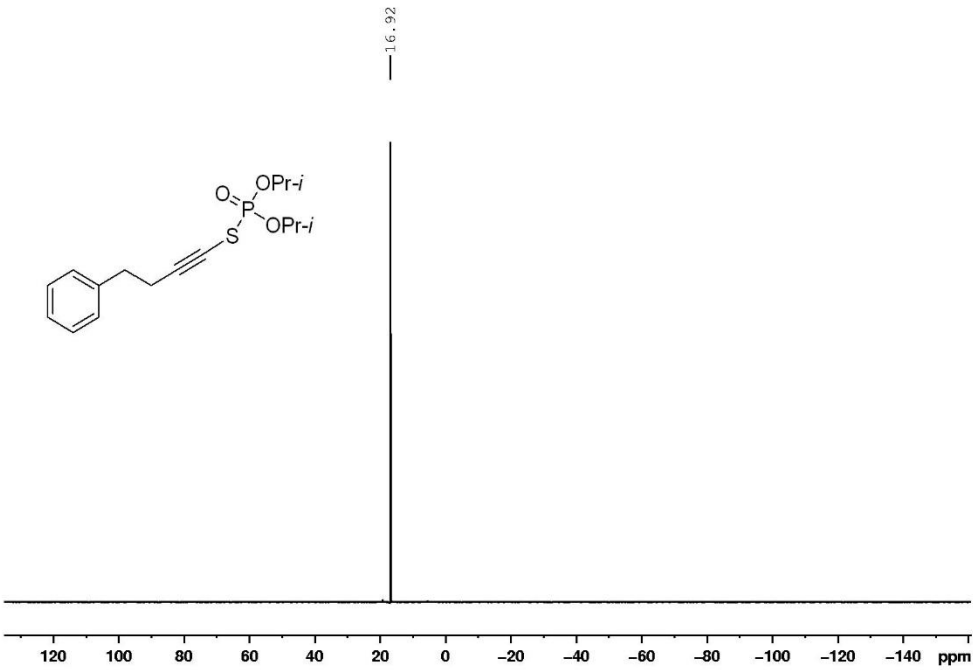
16


4.889
4.879
4.874
4.869
4.864
4.853
2.485
2.473
2.463
2.460
2.450
2.371
2.368
2.364
2.358
2.355
2.351
2.343
2.147
2.143
2.139
2.136
2.132
2.128
2.124
2.120
2.116
1.464
1.451
1.447
1.439
1.424
1.414
1.398
1.394
1.382
1.369
OPr-i
OPr-i
9
8
7
6
5
4
3
2
1
0
ppm
2.00
2.09
1.97
2.17
16.00
3.01

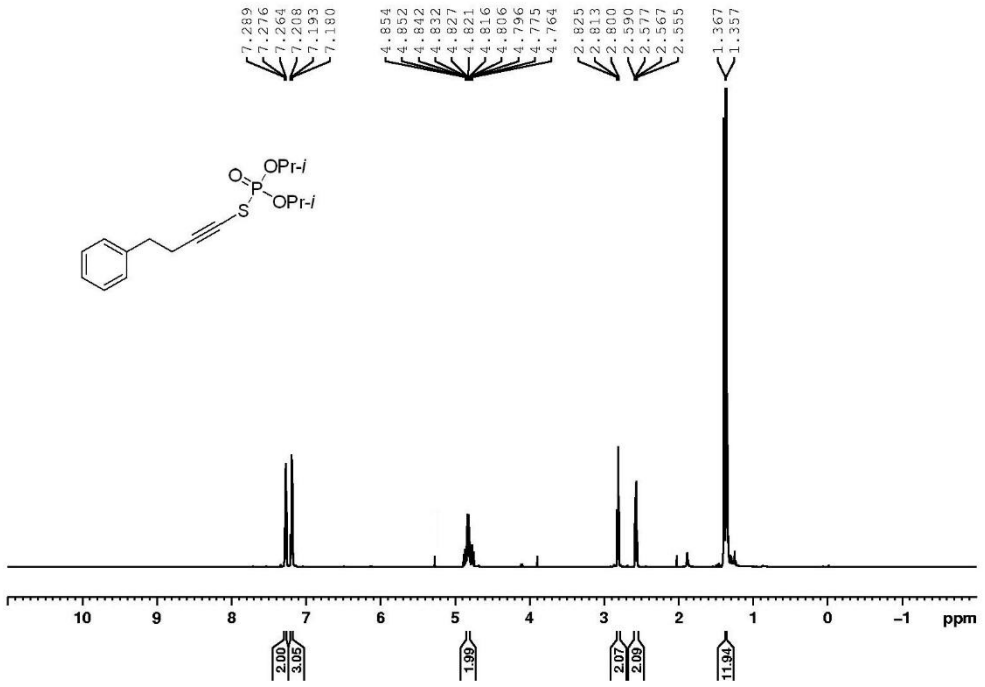
16


92.33
92.27
81.72
77.89
77.64
77.03
76.81
74.27
74.23
60.88
60.81
31.02
23.85
23.83
23.50
23.46
21.92
20.69
20.67
18.84
18.82
18.38
13.64
OPr-i
OPr-i
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10 ppm

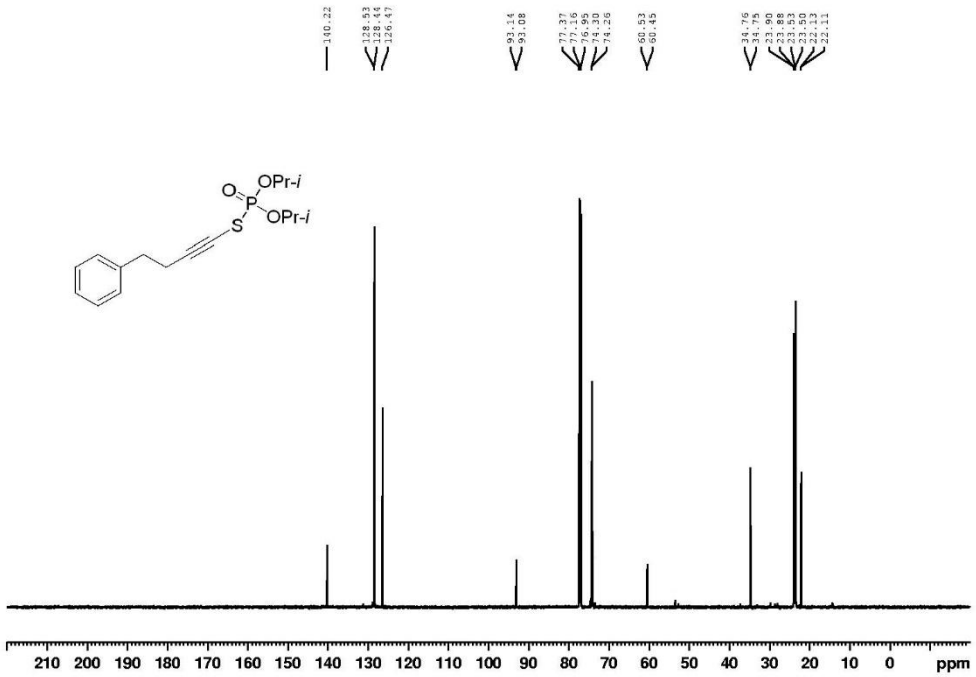
17


16.92
OPr-i
OPr-i
O
P
S
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
ppm

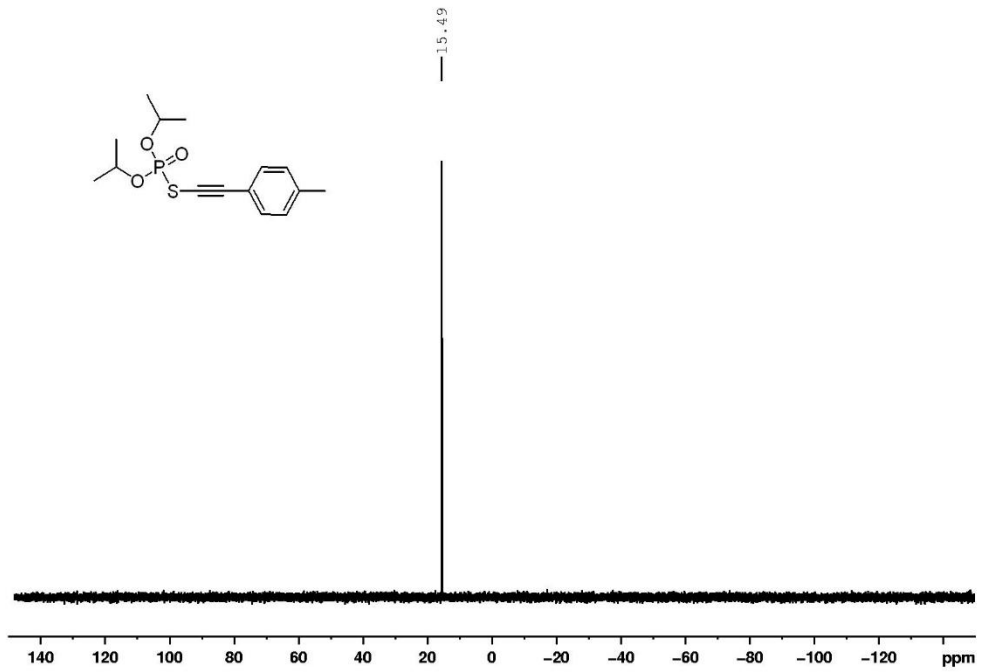
17


7.289
7.276
7.264
7.208
7.193
7.180
4.854
4.852
4.842
4.832
4.827
4.821
4.816
4.806
4.796
4.775
4.764
2.825
2.813
2.800
2.590
2.577
2.567
2.555
1.367
1.357
OPr-i
OPr-i
O
P
S
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
2.00
3.05
1.99
2.07
2.09
11.94

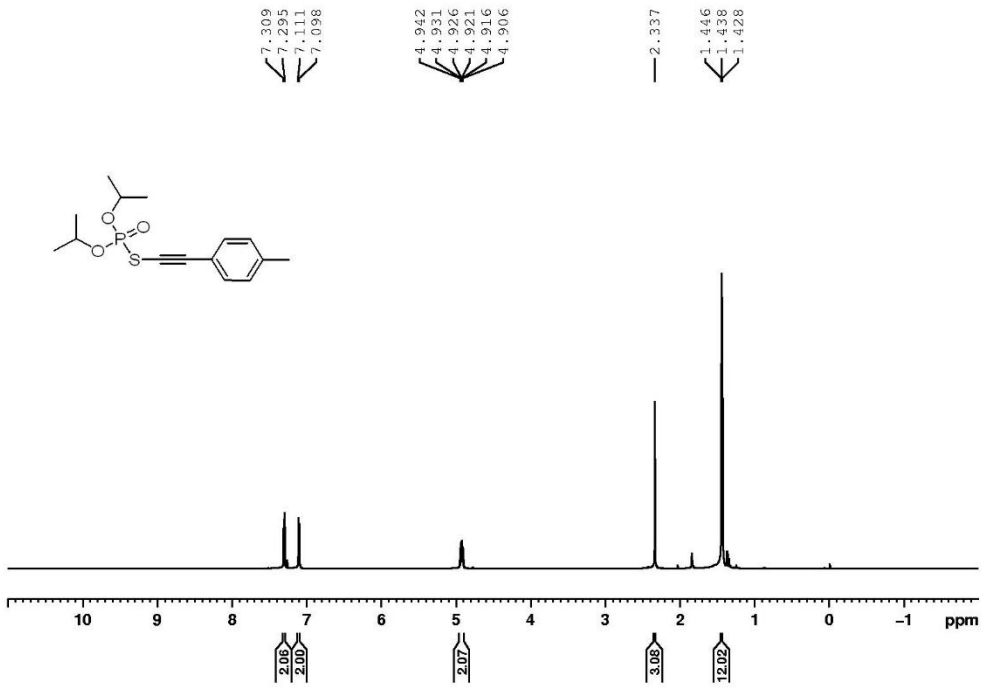
17


140.22
128.93
128.44
126.47
93.14
93.08
77.37
77.16
76.95
74.30
74.26
60.53
60.45
34.76
34.75
23.90
23.88
23.53
23.50
22.13
22.11
OPr-i
OPr-i
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

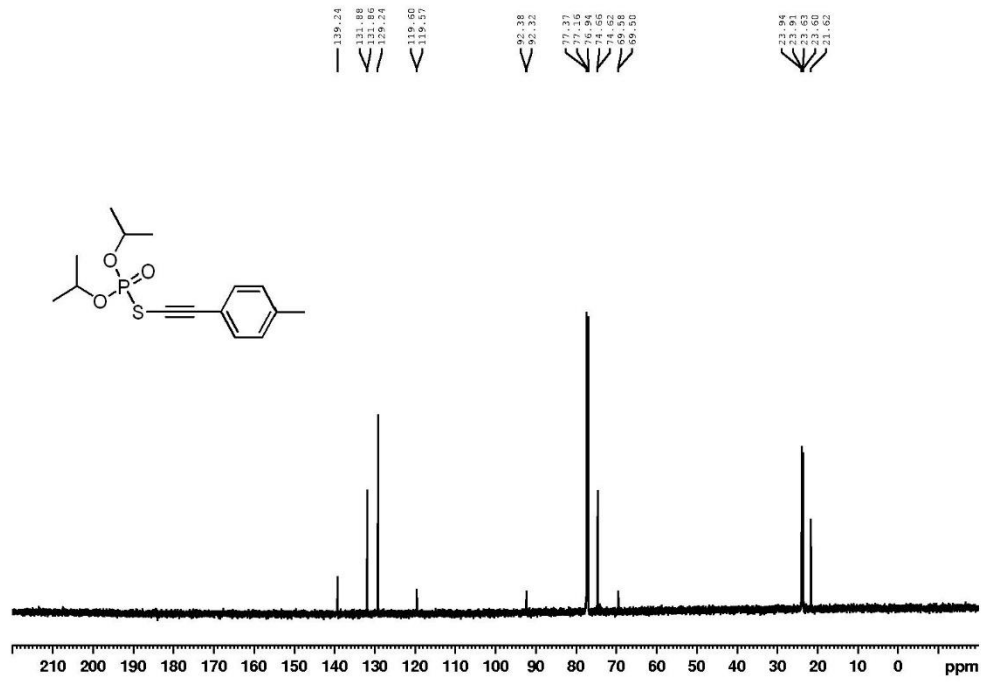
18


15.49
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

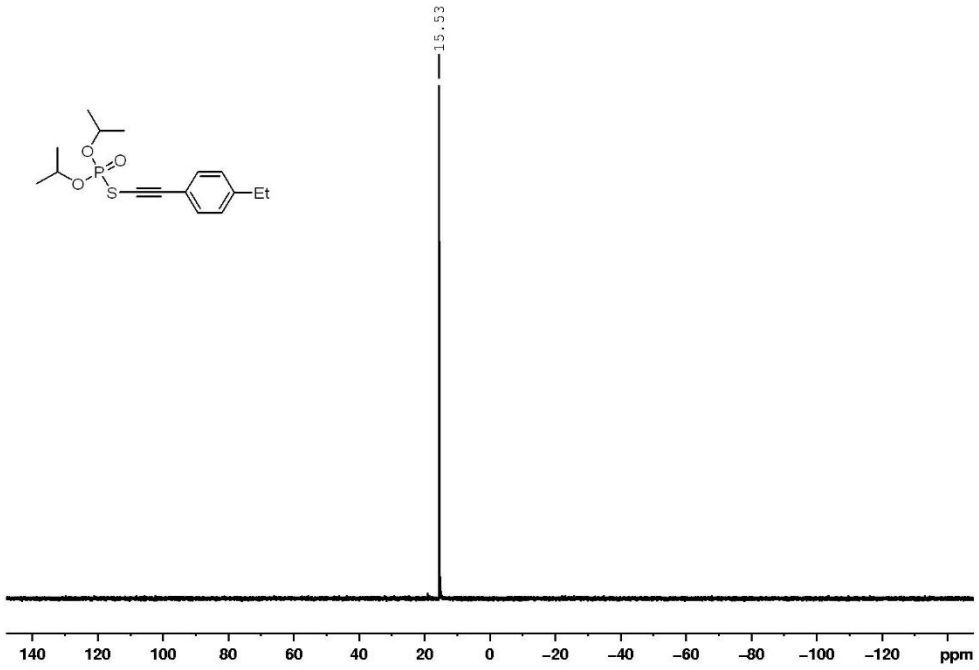
18


7.309
7.295
7.111
7.098
4.942
4.931
4.926
4.921
4.916
4.906
2.337
1.446
1.438
1.428
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
2.06
2.00
2.07
3.08
12.02

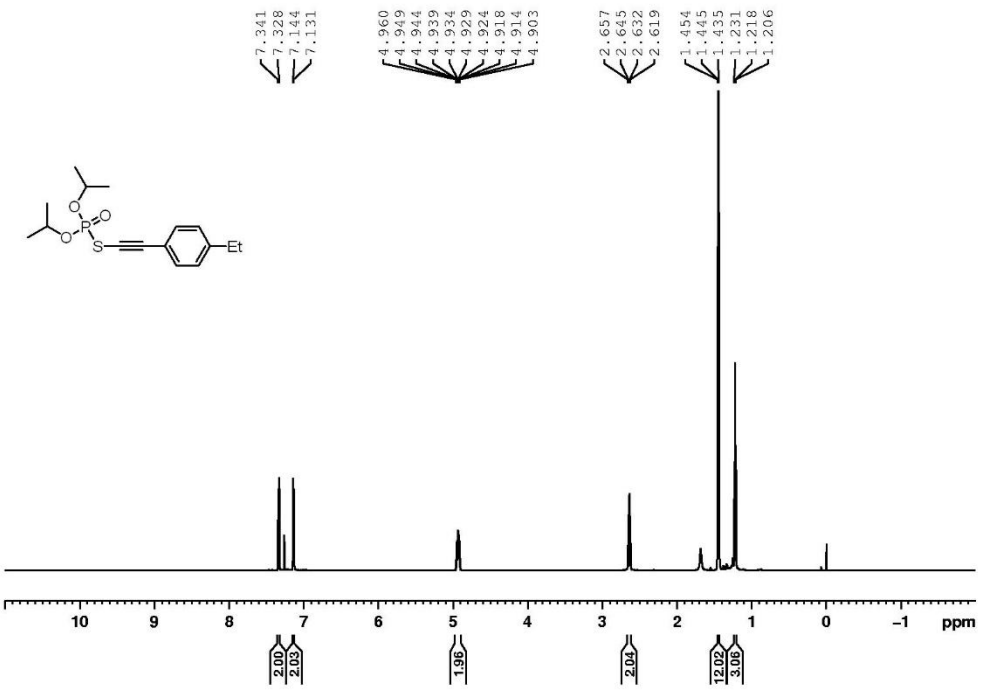
18


139.24
131.88
131.86
129.24
119.60
119.57
92.38
92.32
77.37
77.16
76.94
74.66
74.62
69.58
69.50
23.94
23.91
23.65
23.60
21.62
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

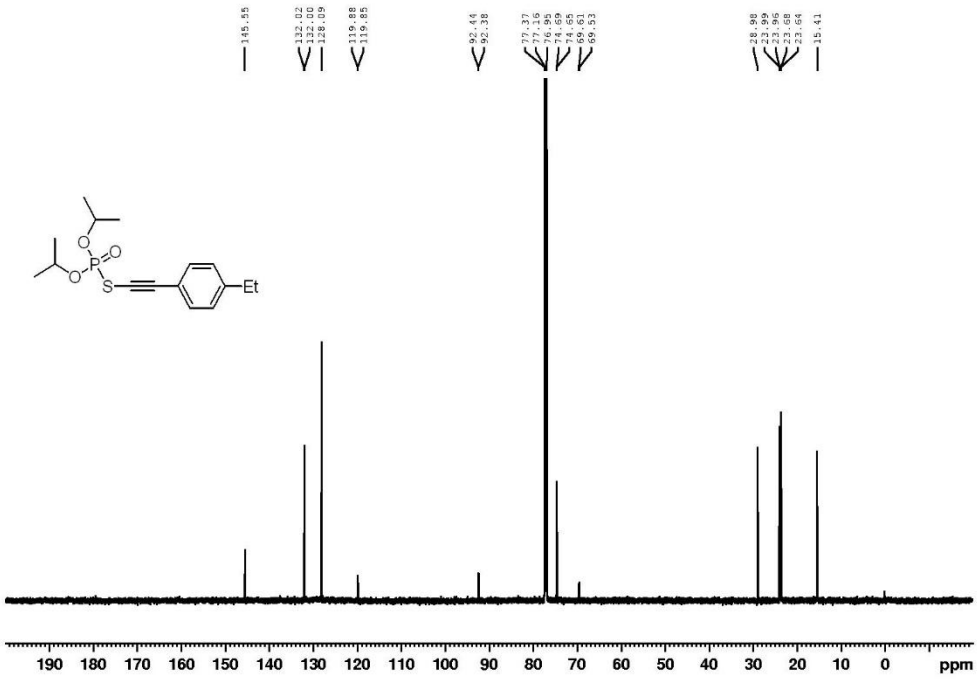
19


15.53
Et
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

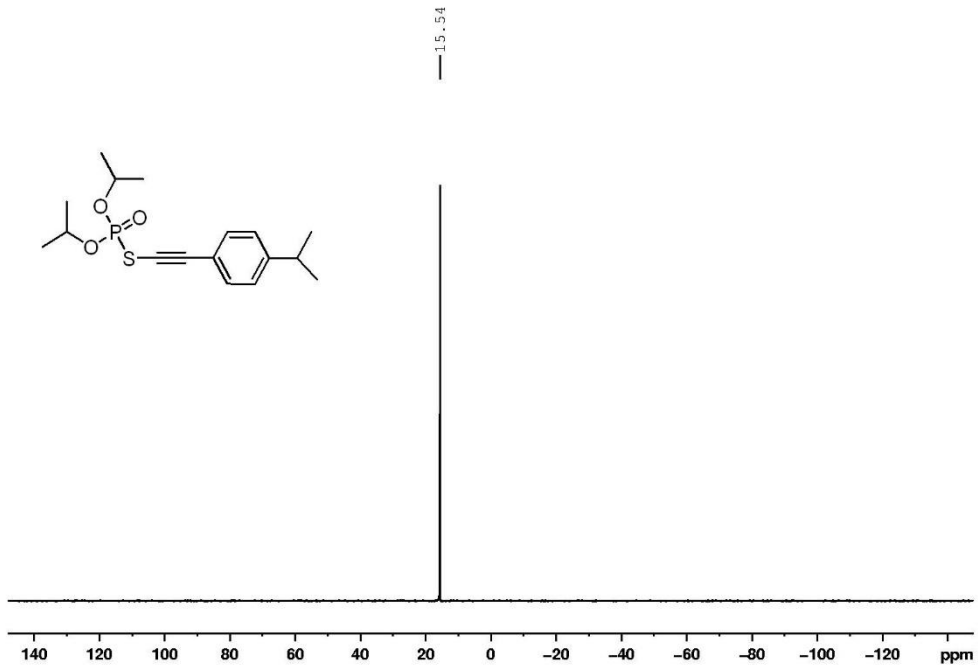
19


7.341
7.328
7.144
7.131
4.960
4.949
4.944
4.939
4.934
4.929
4.924
4.918
4.914
4.903
2.657
2.645
2.632
2.619
1.454
1.445
1.435
1.231
1.218
1.206
Et
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
2.00
2.03
1.96
2.04
12.02
3.06

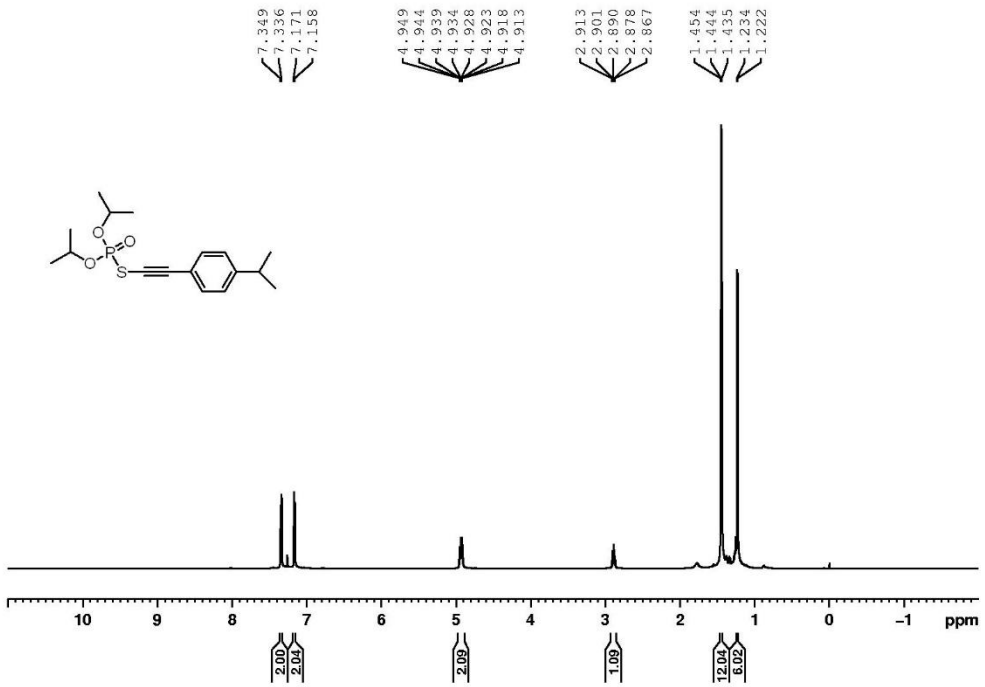
19


145.55
132.02
132.00
128.09
119.88
119.85
92.44
92.38
77.37
77.16
76.95
74.69
74.65
69.61
69.53
28.98
23.99
23.96
23.68
23.64
15.41
Et
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

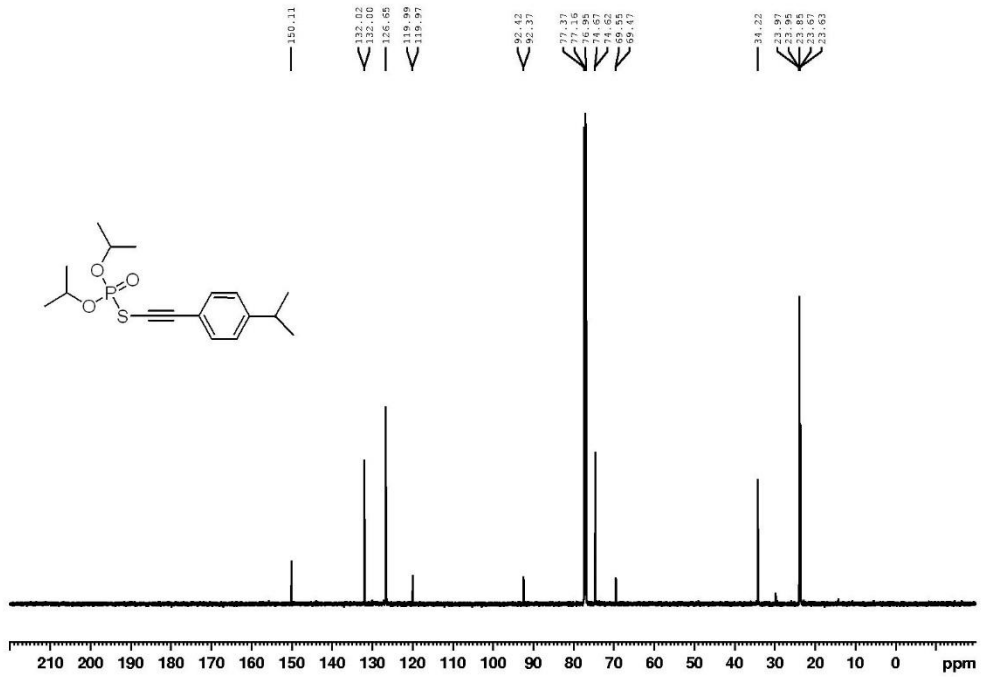
20


15.54
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

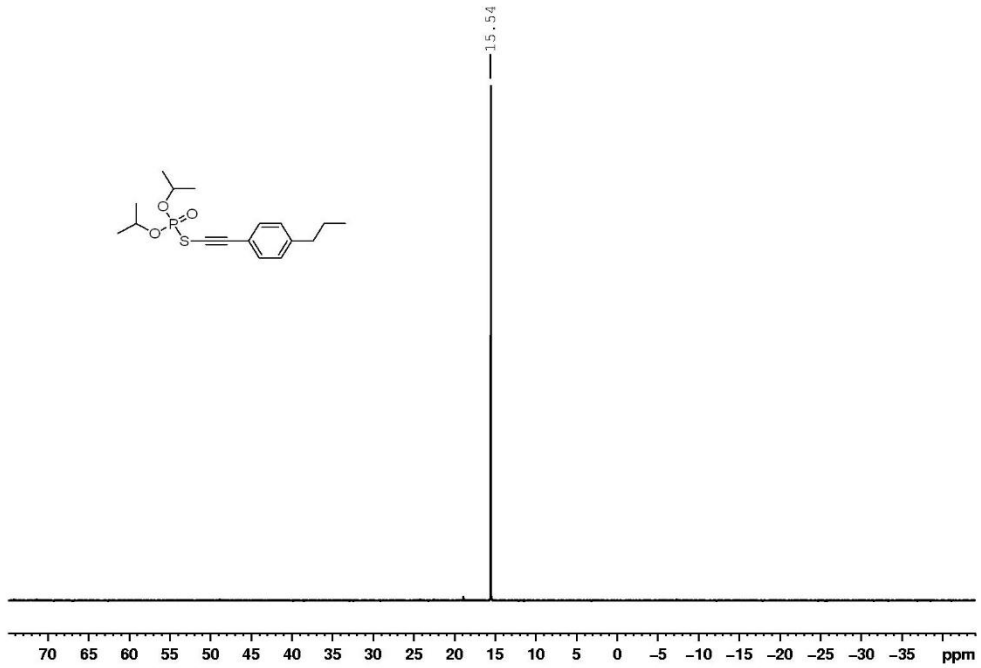
20


7.349
7.336
7.171
7.158
4.949
4.944
4.939
4.934
4.928
4.923
4.918
4.913
2.913
2.901
2.890
2.878
2.867
1.454
1.444
1.435
1.234
1.222
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
2.00
2.04
2.09
1.09
12.04
6.02

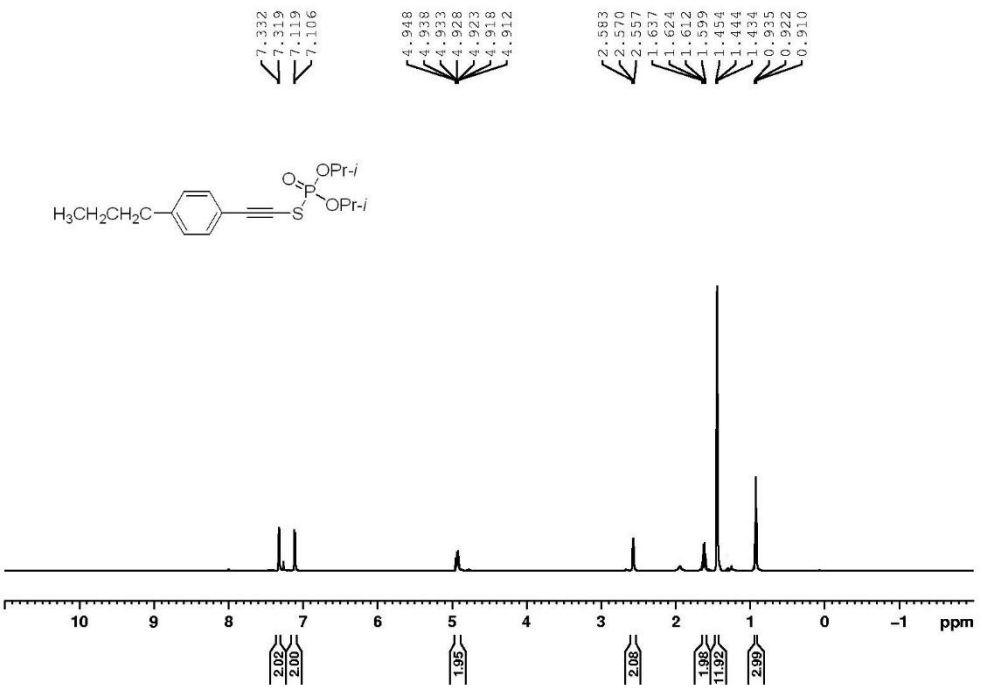
20


150.11
132.02
132.00
126.65
119.99
119.97
92.42
92.37
77.37
77.16
76.95
74.67
74.62
69.55
69.47
34.22
23.97
23.95
23.85
23.67
23.63
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

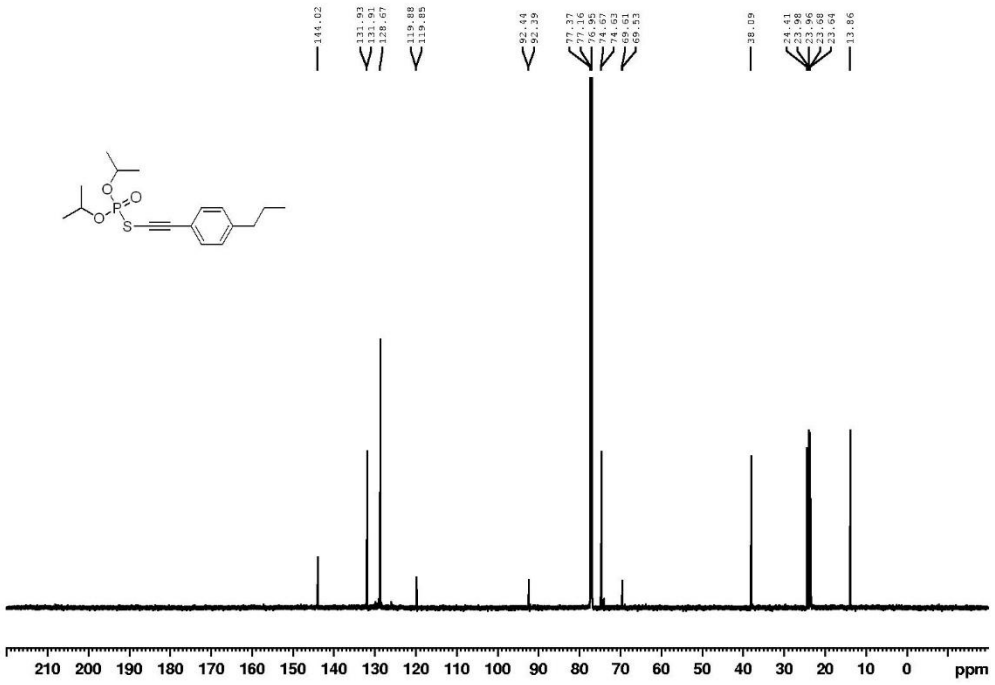
21


15.54
70 65 60 55 50 45 40 35 30 25 20 15 10 5 0 −5 −10 −15 −20 −25 −30 −35 ppm

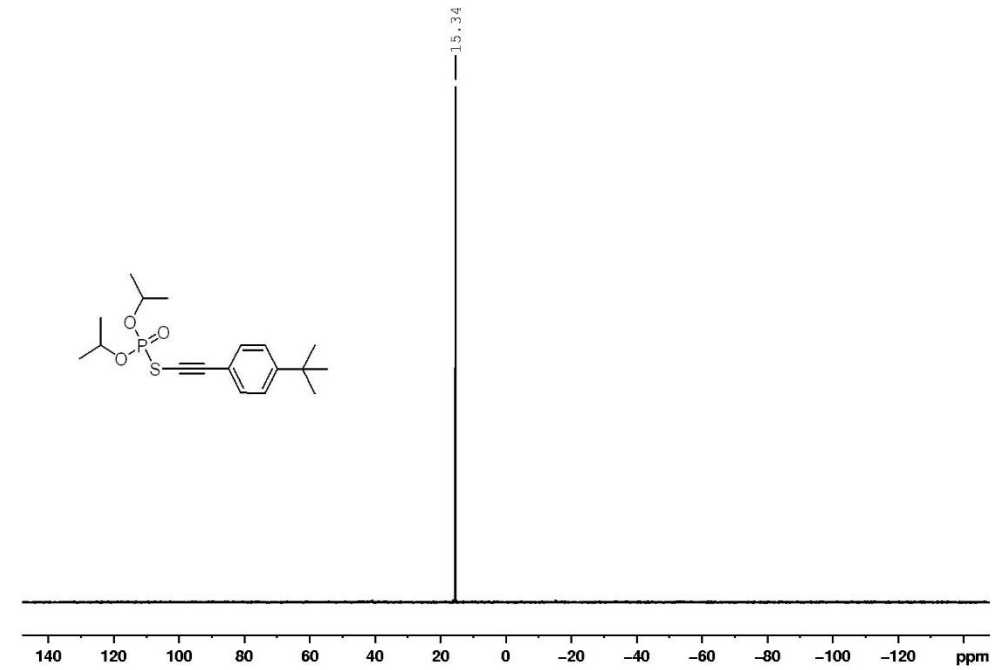
21


7.332
7.319
7.119
7.106
4.948
4.938
4.933
4.928
4.923
4.918
4.912
2.583
2.570
2.557
1.637
1.624
1.612
1.599
1.454
1.444
1.434
0.935
0.922
0.910
OPr-i
OPr-i
H3CH2CH2C
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
2.02
2.00
1.95
2.08
1.98
11.92
2.99

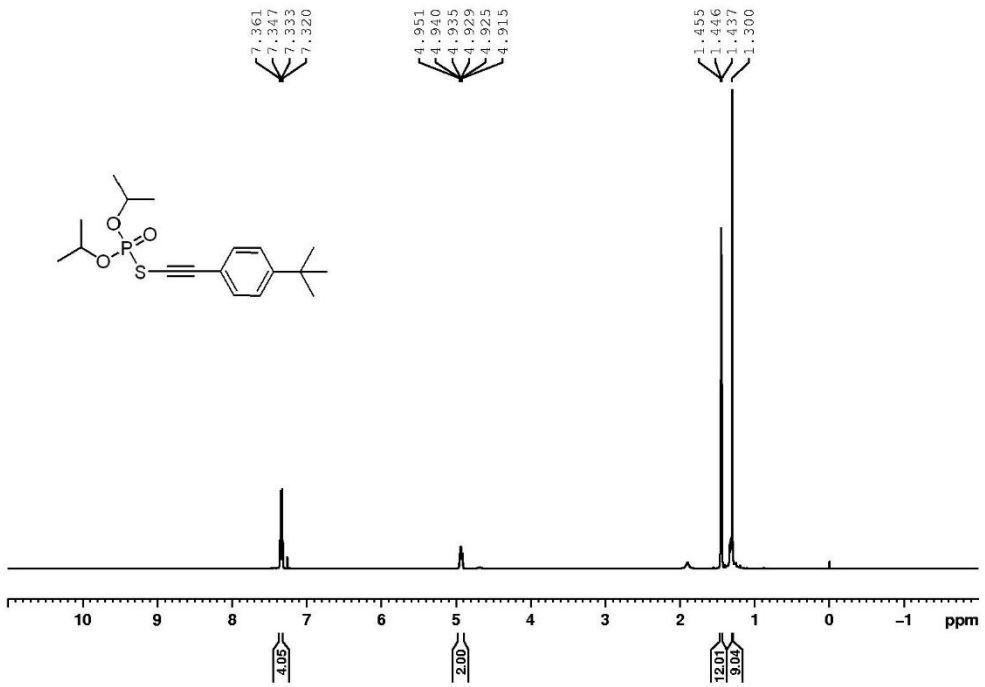
21


144.02
131.93
131.91
128.67
119.88
119.85
92.44
92.19
77.37
77.16
76.96
74.67
74.63
69.61
69.53
38.09
24.41
23.98
23.96
23.68
23.64
13.86
O
P
O
O
S
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

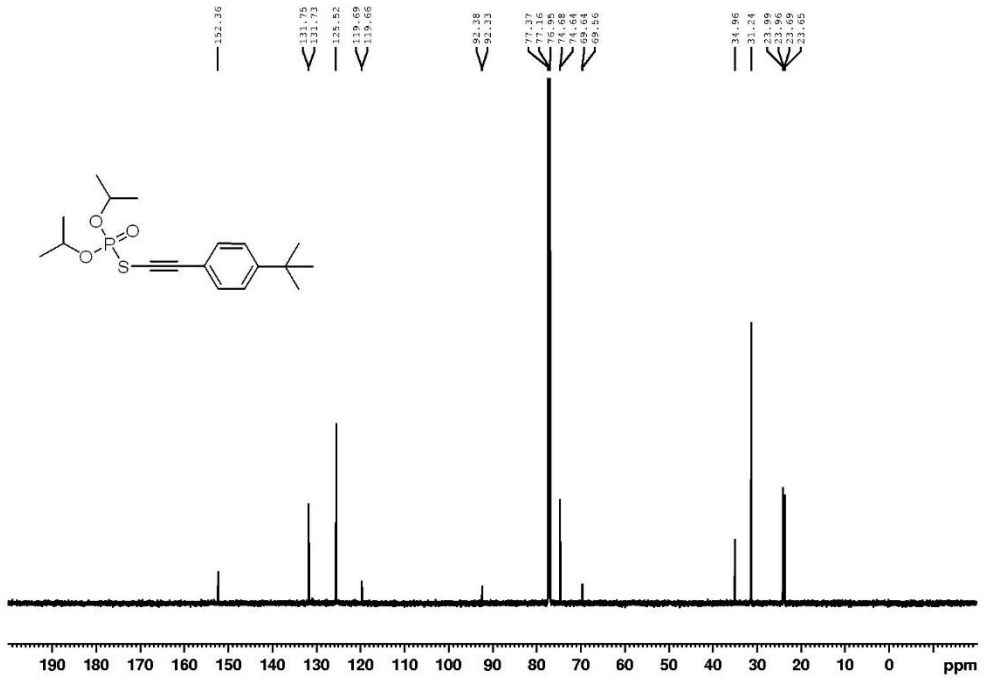
22


15.34
O
P
O
O
S
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

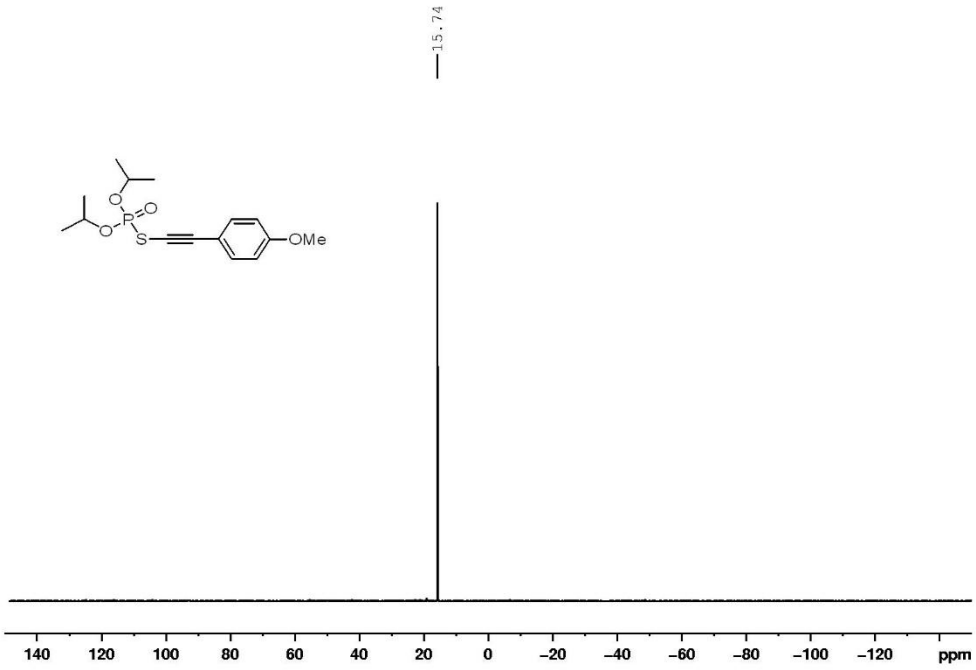
22


7.361
7.347
7.333
7.320
4.951
4.940
4.935
4.929
4.925
4.915
1.455
1.446
1.437
1.300
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
4.05
2.00
12.01
9.04

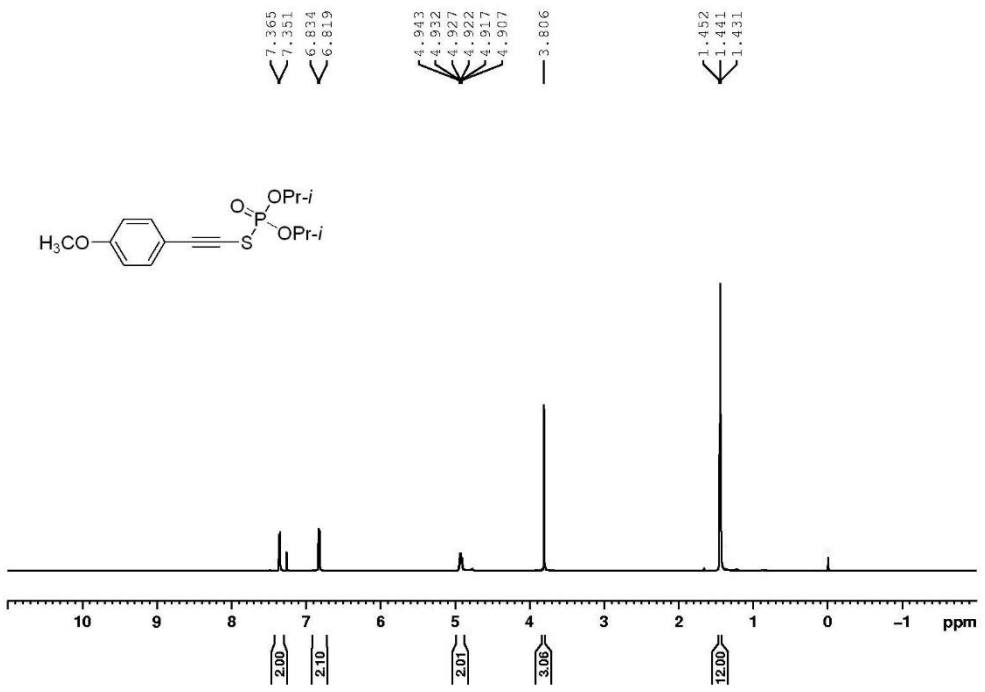
22


152.36
131.75
131.73
125.52
119.69
119.66
92.38
92.33
77.37
77.16
76.95
74.68
74.64
69.64
69.56
34.96
31.24
23.99
23.96
23.89
23.65
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

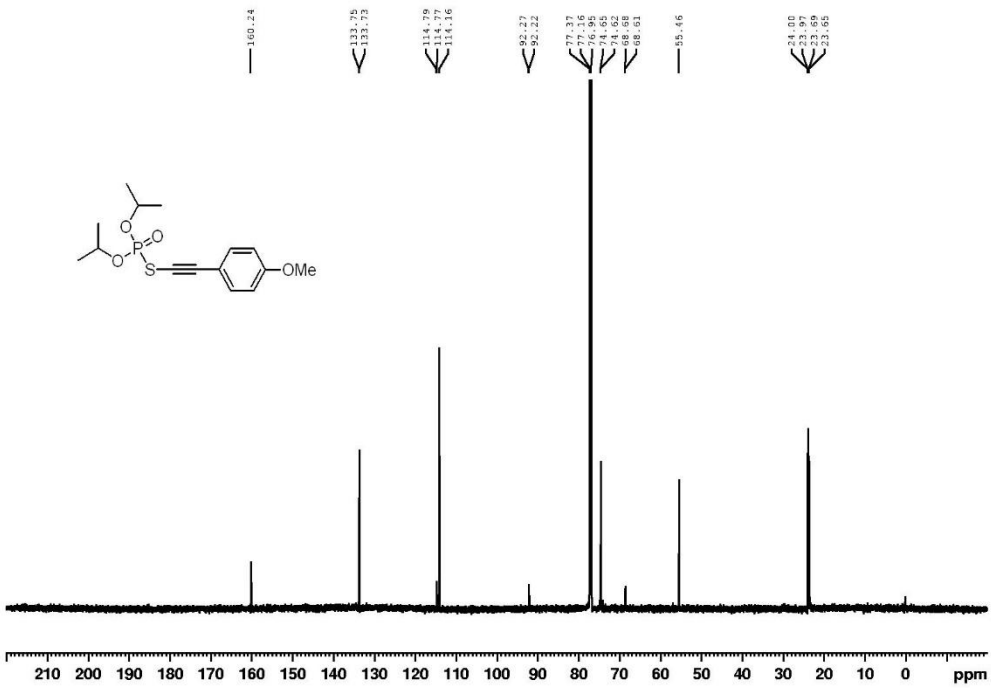
23


15.74
OMe
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

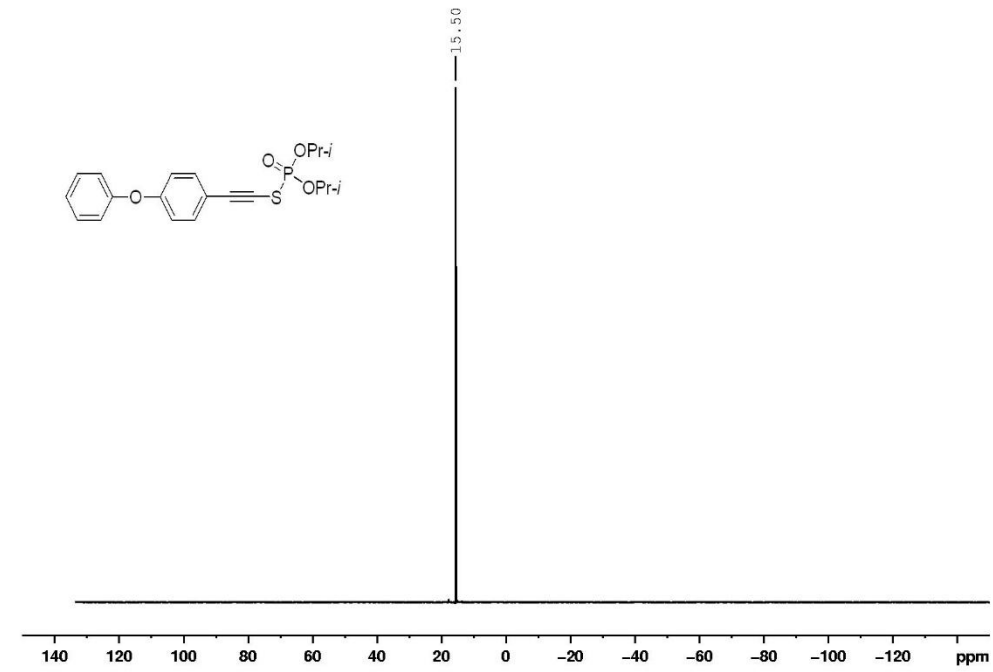
23


7.365
7.351
6.834
6.819
4.943
4.932
4.927
4.922
4.917
4.907
3.806
1.452
1.441
1.431
OPr-i
OPr-i
H3CO
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
2.00
2.10
2.01
3.06
12.00

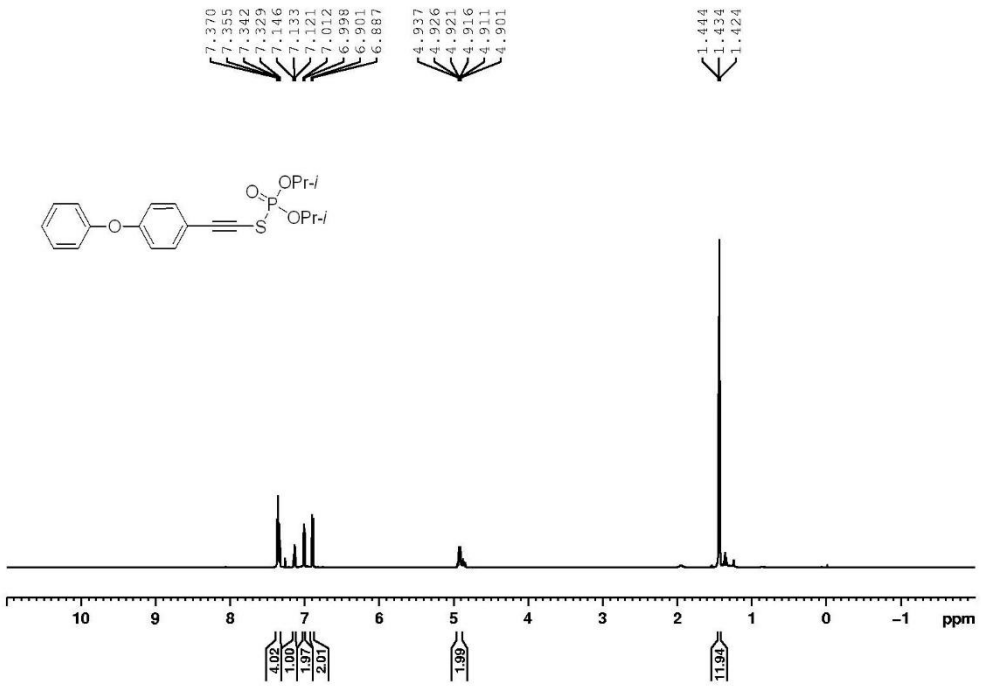
23


160.24
133.75
133.73
114.79
114.77
114.16
92.27
92.22
77.37
77.16
76.95
74.65
74.62
68.68
68.61
55.46
24.00
23.97
23.89
23.65
OMe
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

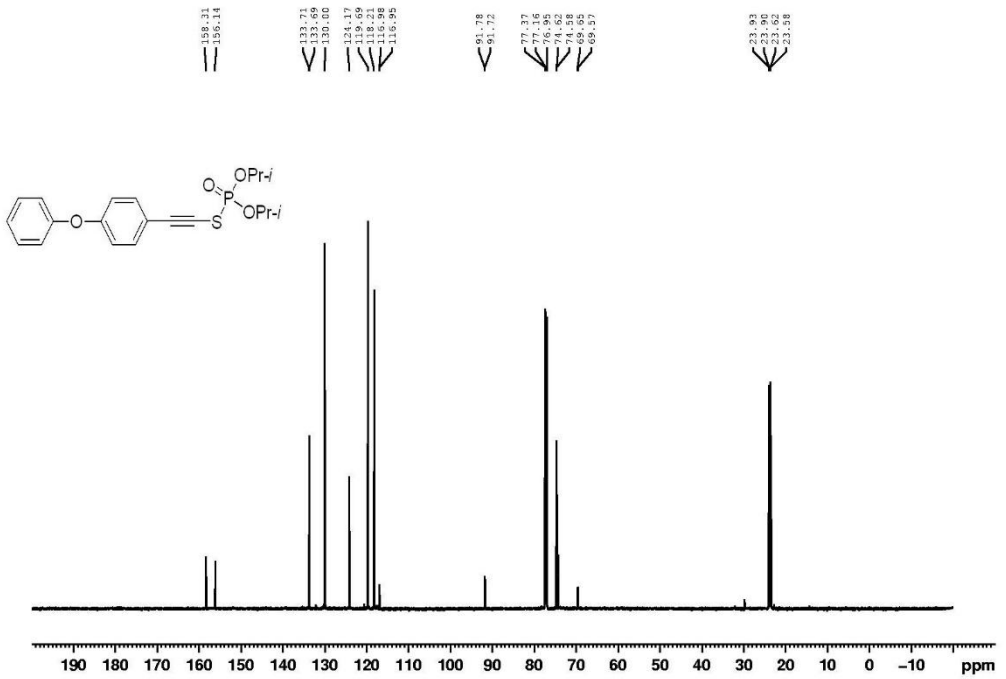
24


15.50
OPr-i
OPr-i
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

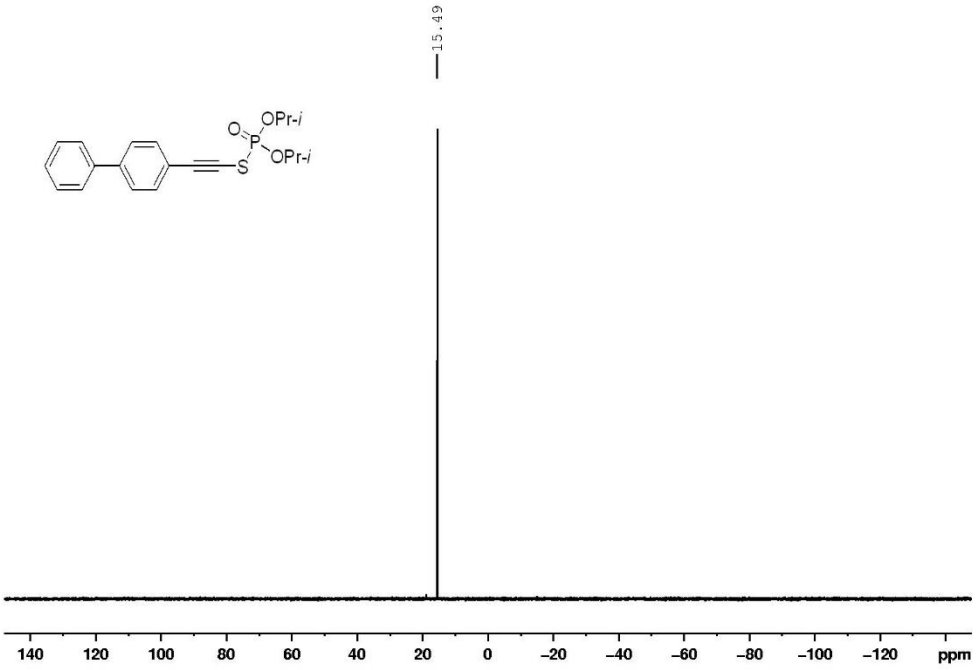
24


7.370
7.355
7.342
7.329
7.146
7.133
7.121
7.012
6.998
6.901
6.887
4.937
4.926
4.921
4.916
4.911
4.901
1.444
1.434
1.424
OPr-i
OPr-i
O
P
S
O
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
4.02
1.00
1.97
2.01
1.99
11.94

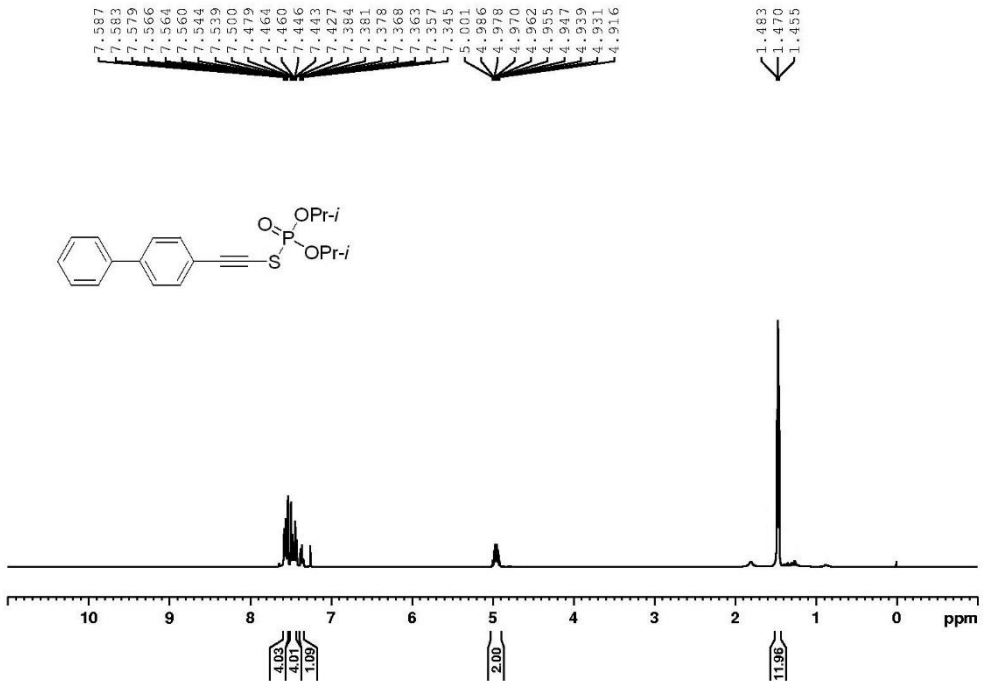
24


158.31
156.14
133.71
133.69
130.00
124.17
119.69
118.21
116.98
116.95
91.78
91.72
77.37
77.16
76.95
74.62
74.58
69.65
69.57
23.93
23.90
23.62
23.38
OPr-i
OPr-i
O
P
S
O
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 ppm

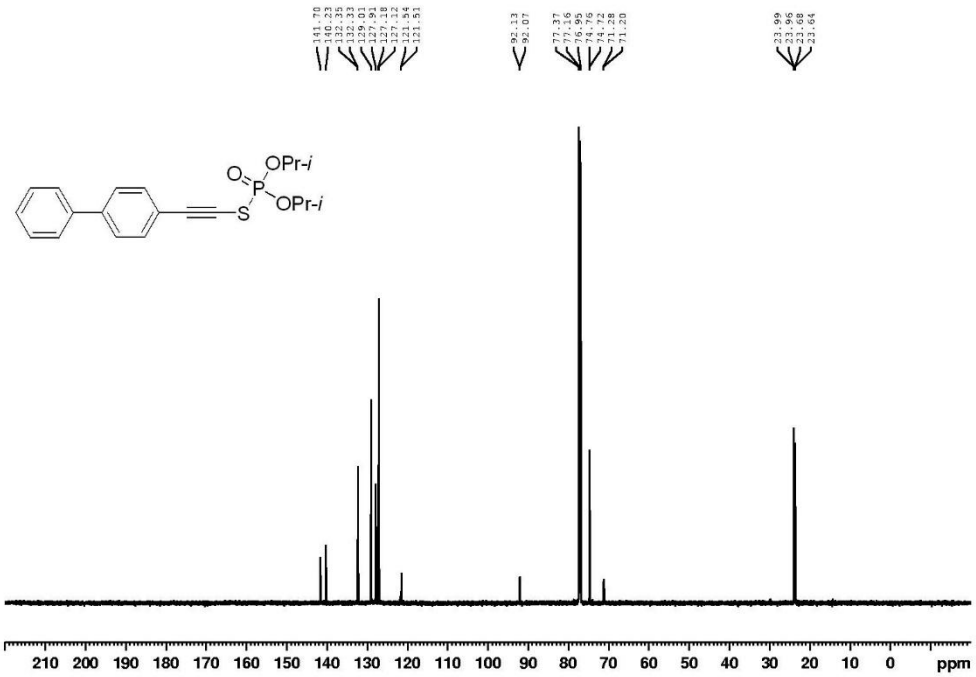
25


15.49
OPr-i
OPr-i
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

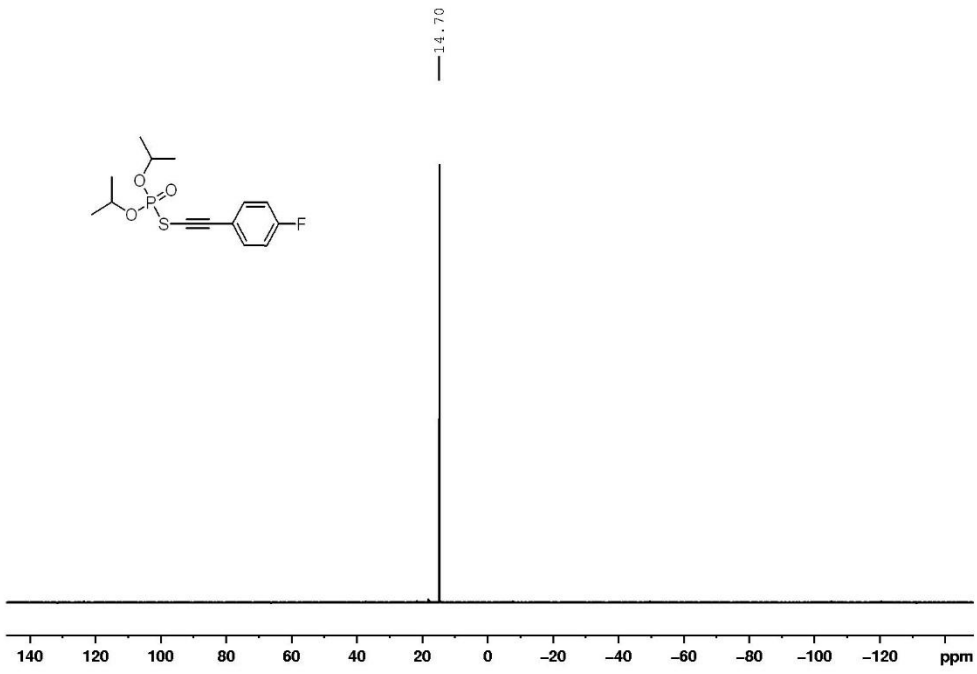
25


7.587
7.583
7.579
7.566
7.564
7.560
7.544
7.539
7.500
7.479
7.464
7.460
7.446
7.443
7.427
7.384
7.381
7.378
7.368
7.363
7.357
7.345
5.001
4.986
4.978
4.970
4.962
4.955
4.947
4.939
4.931
4.916
1.483
1.470
1.455
OPr-i
OPr-i
10
9
8
7
6
5
4
3
2
1
0
ppm
4.03
4.01
1.09
2.00
11.96

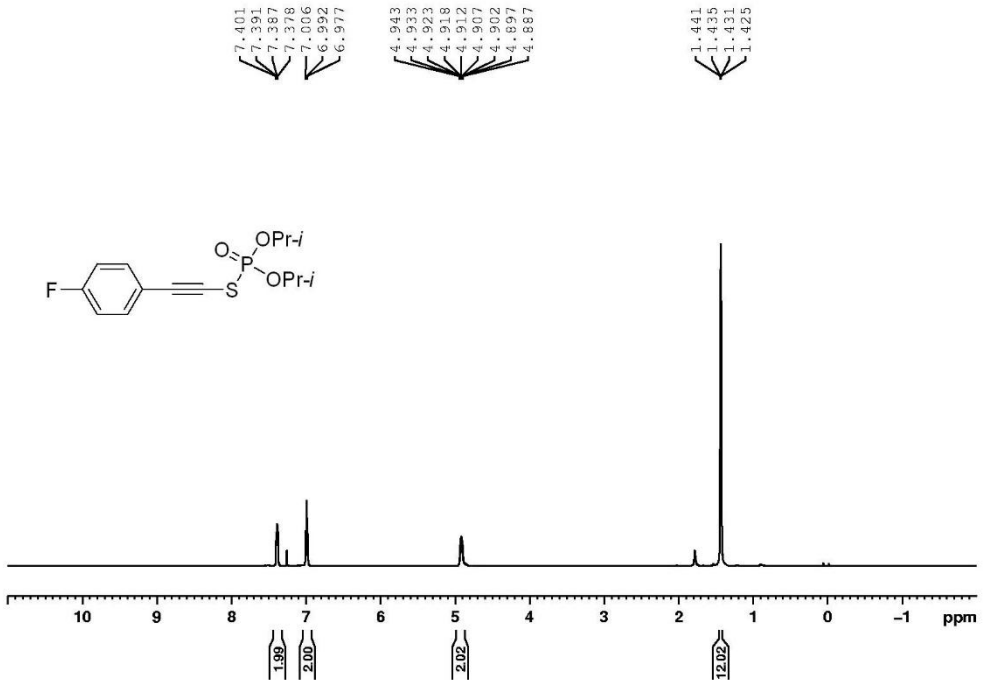
25


141.70
140.23
132.35
132.33
129.01
127.91
127.18
127.02
121.44
121.51
92.13
92.07
77.37
77.16
76.95
76.76
74.72
71.28
71.20
23.99
23.96
23.68
23.64
OPr-i
OPr-i
O
P
S
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

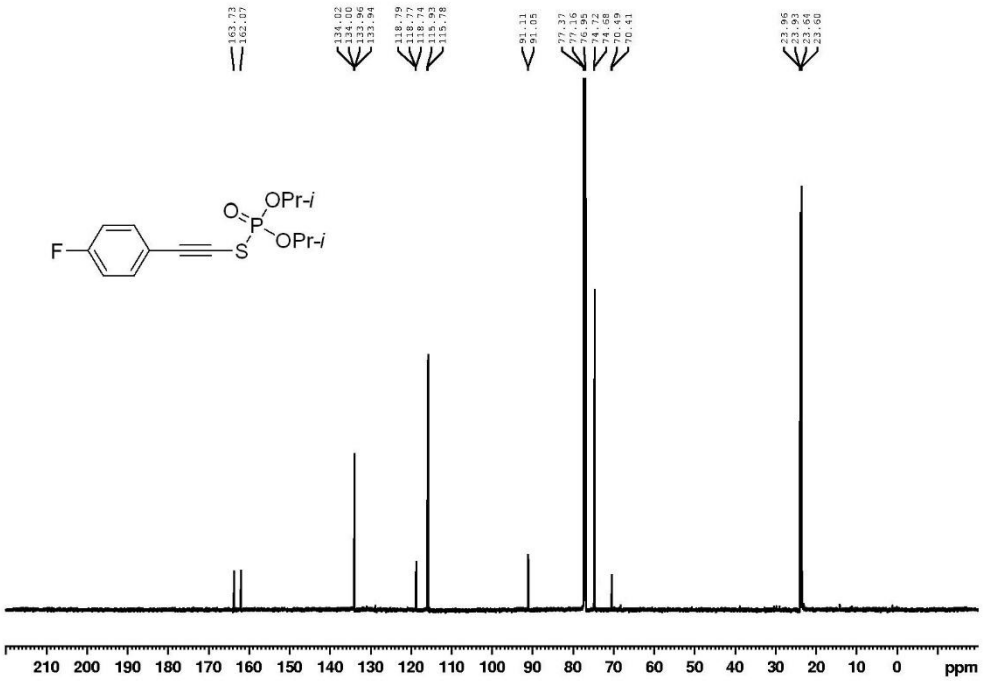
26


14.70
O
P
S
F
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

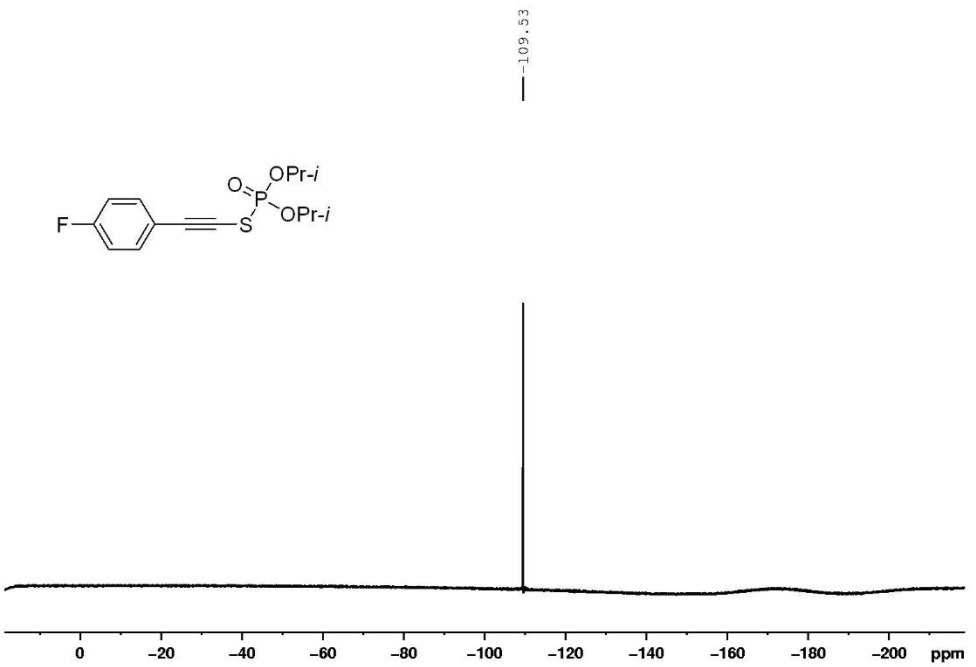
26


7.401
7.391
7.387
7.378
7.006
6.992
6.977
4.943
4.933
4.923
4.918
4.912
4.907
4.902
4.897
4.887
1.441
1.435
1.431
1.425
OPr-i
OPr-i
F
S
O
P
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
1.99
2.00
2.02
12.02

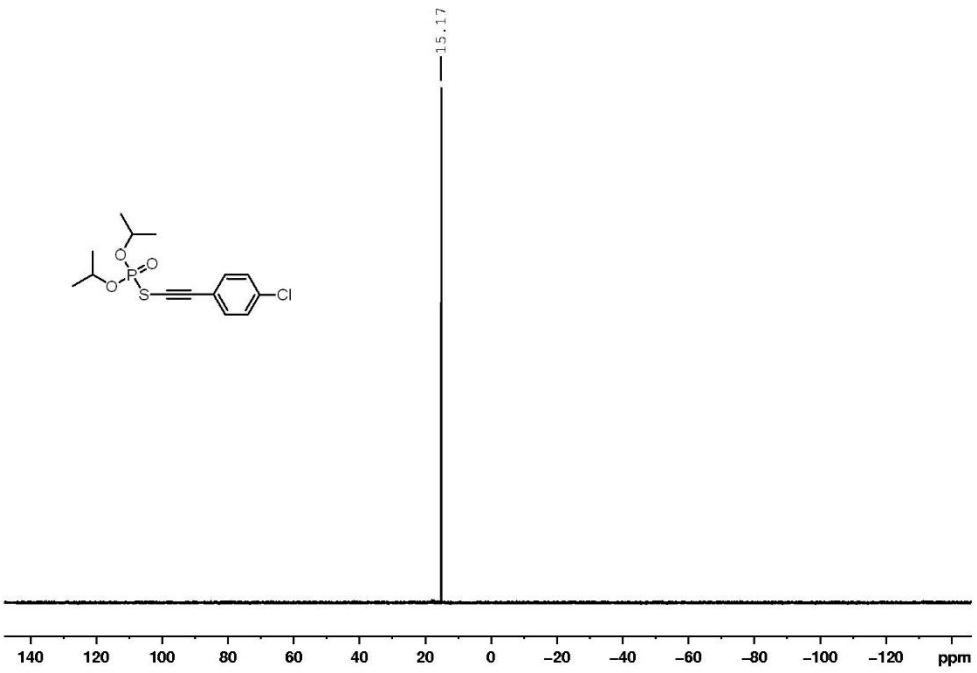
26


163.73
162.07
134.02
134.00
133.96
133.94
118.79
118.77
118.74
115.93
115.78
91.11
91.05
77.37
77.16
76.95
74.72
74.68
70.49
70.41
23.96
23.93
23.64
23.60
OPr-i
OPr-i
F
S
O
P
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

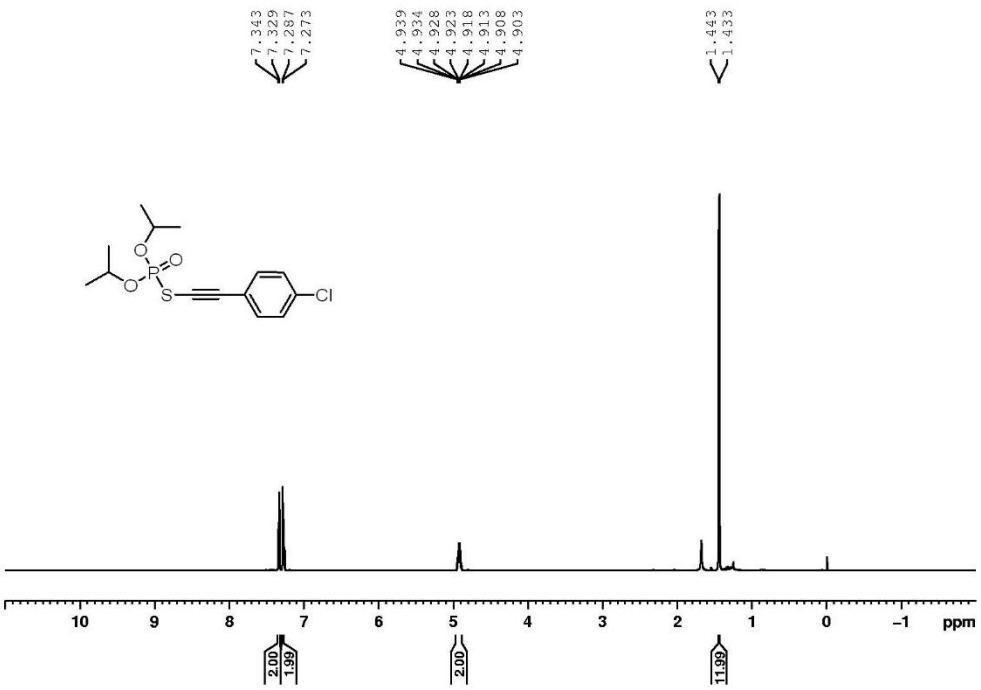
26


-109.53
OPr-i
O
P
OPr-i
F
S
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
ppm

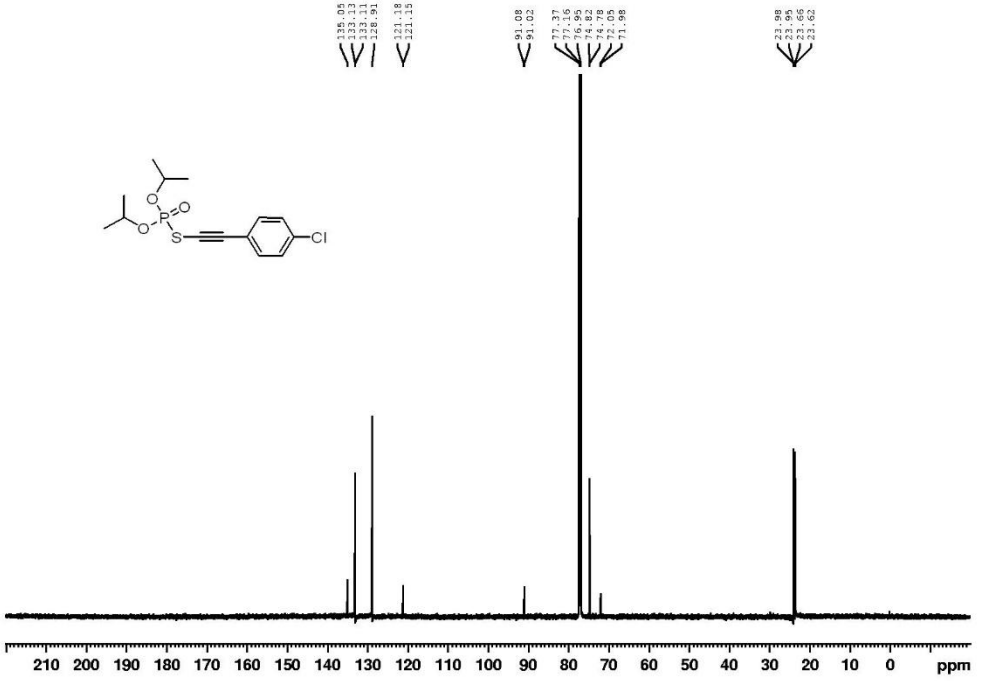
27


15.17
O
O
P
O
S
Cl
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

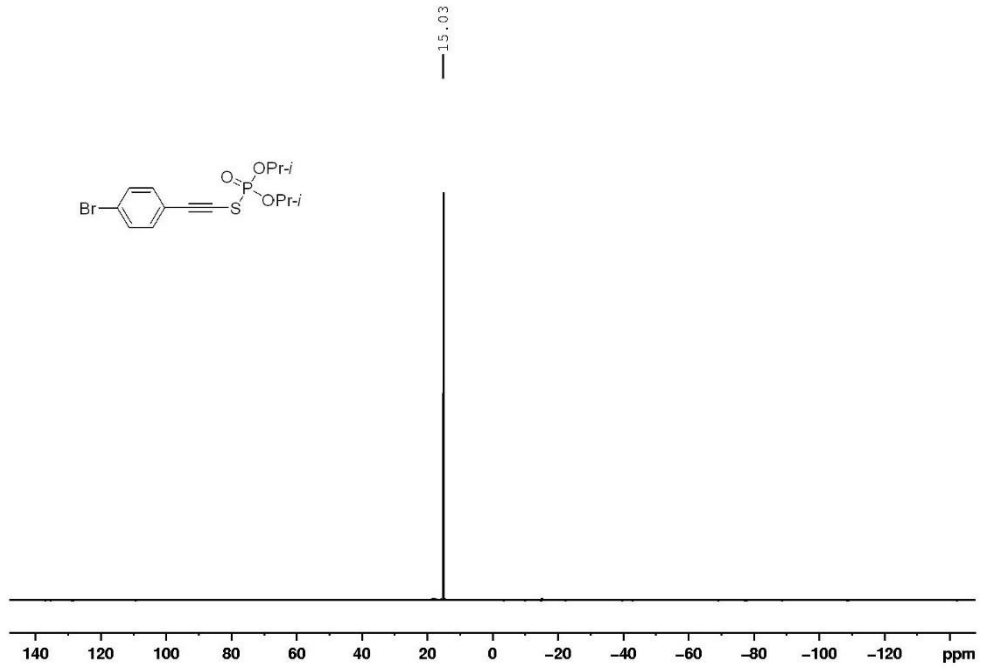
27


7.343
7.329
7.287
7.273
4.939
4.934
4.928
4.923
4.918
4.913
4.908
4.903
1.443
1.433
Cl
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
2.00
1.99
2.00
11.99

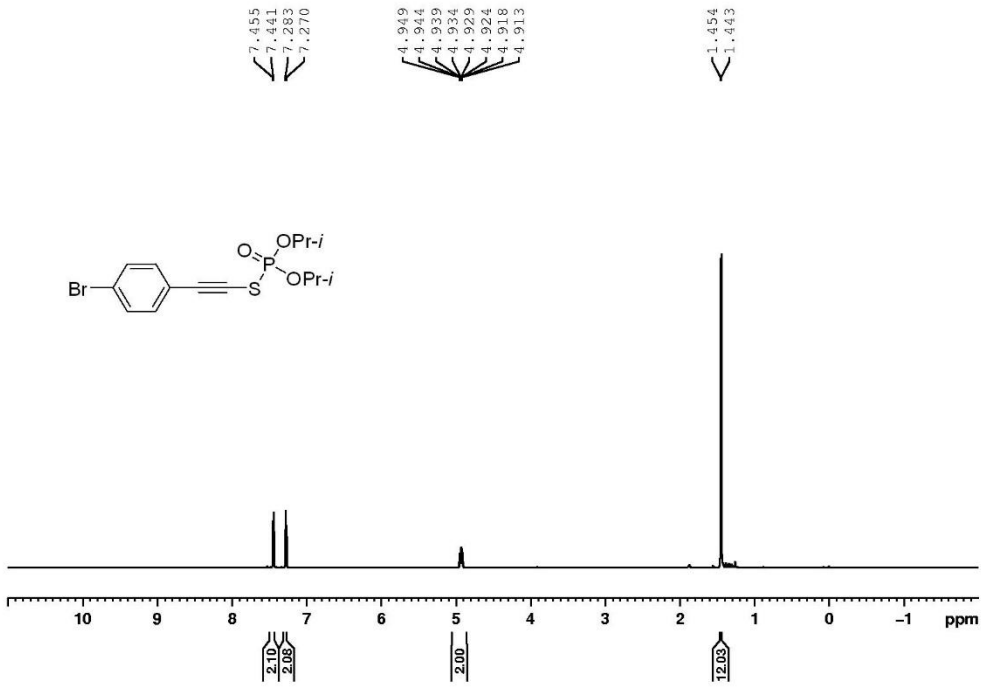
27


135.05
133.33
133.11
128.91
121.18
121.15
91.08
91.02
77.37
77.16
76.96
74.82
74.78
72.05
71.98
23.98
23.95
23.66
23.62
Cl
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

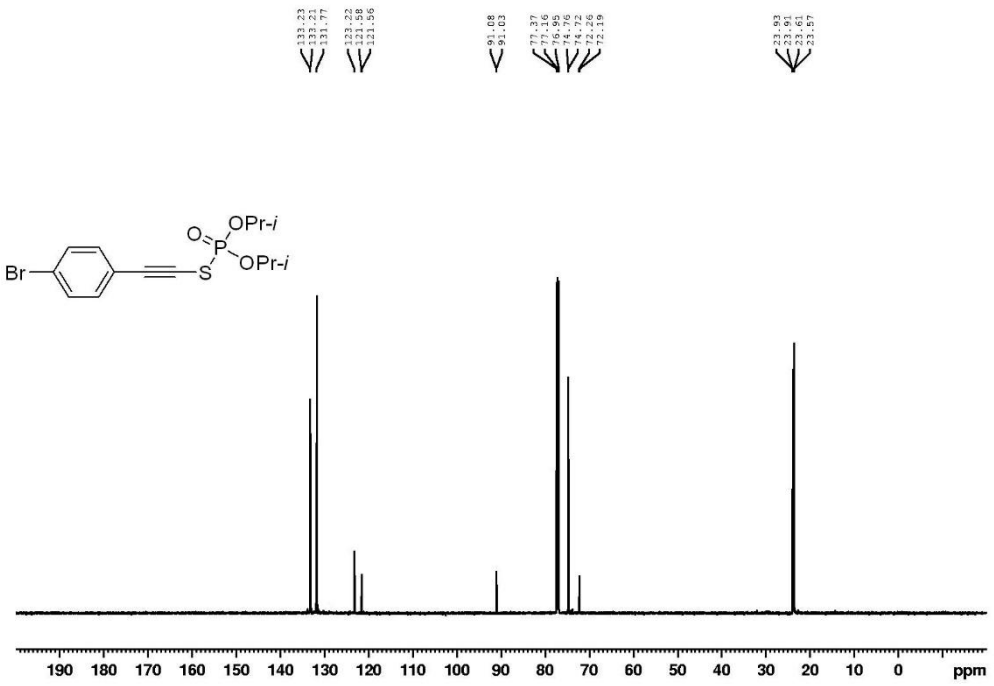
28


15.03
Br
OPr-i
OPr-i
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

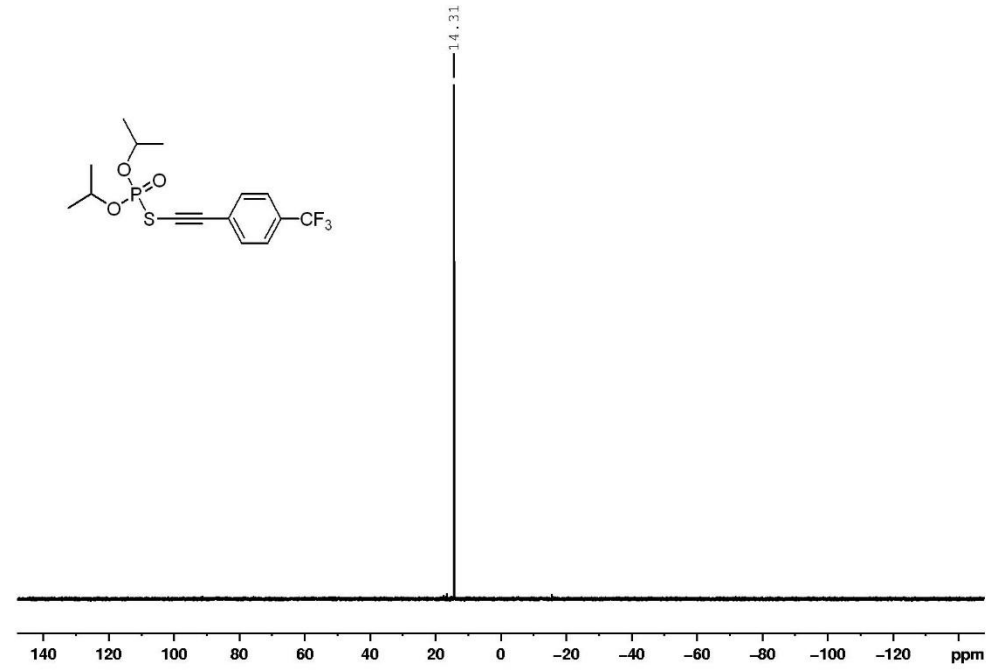
28


7.455
7.441
7.283
7.270
4.949
4.944
4.939
4.934
4.929
4.924
4.918
4.913
1.454
1.443
Br
OPr-i
OPr-i
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
2.10
2.08
2.00
12.03

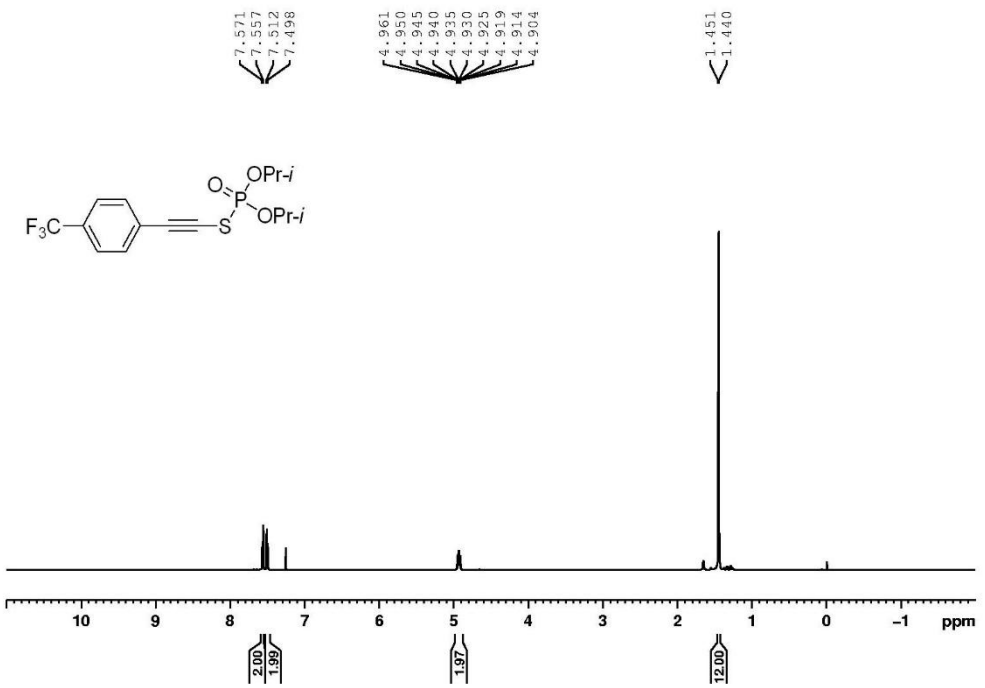
28


133.23
133.21
131.77
123.22
121.58
121.56
91.68
91.03
77.37
77.16
76.95
74.76
74.72
72.26
72.19
23.93
23.91
23.61
23.57
Br
O
P
S
OPr-i
OPr-i
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

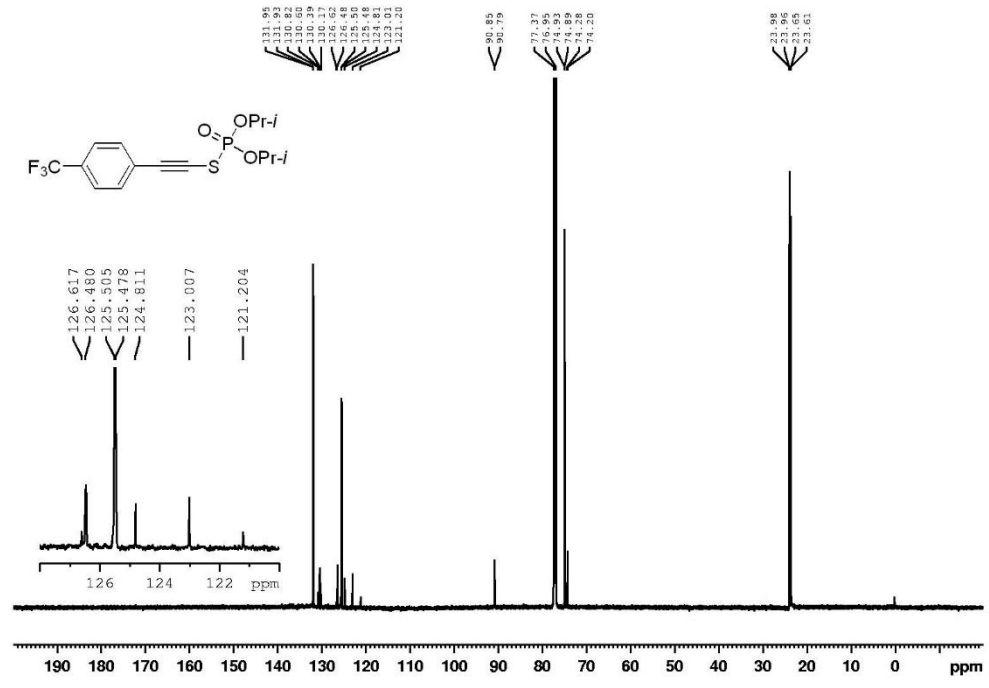
29


14.31
O
P
O
O
S
CF3
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

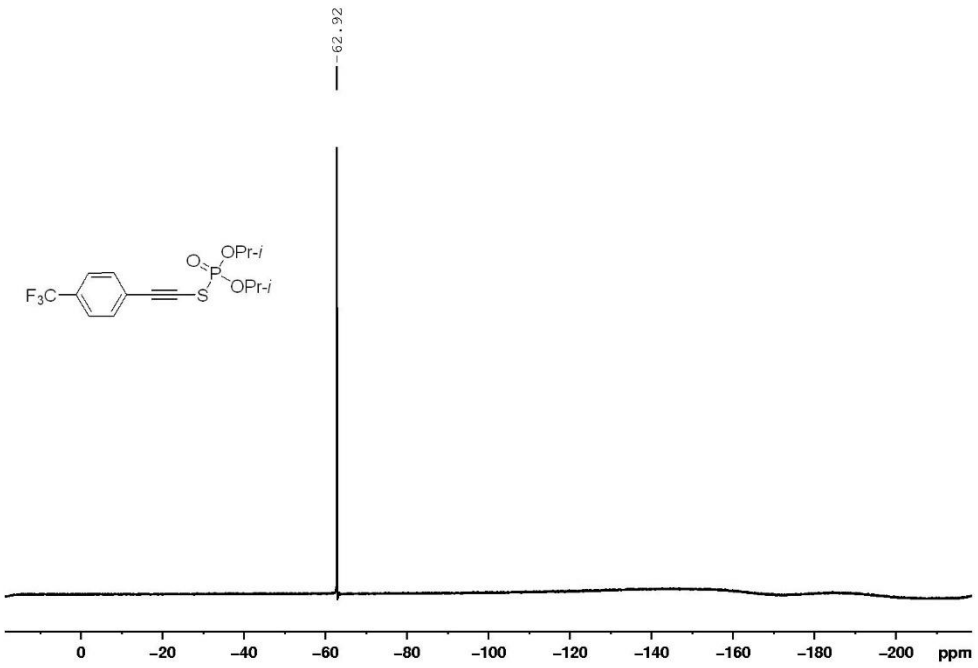
29


7.571
7.557
7.512
7.498
4.961
4.950
4.945
4.940
4.935
4.930
4.925
4.919
4.914
4.904
1.451
1.440
OPr-i
OPr-i
F3C
S
P
O
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
2.00
1.99
1.97
12.00

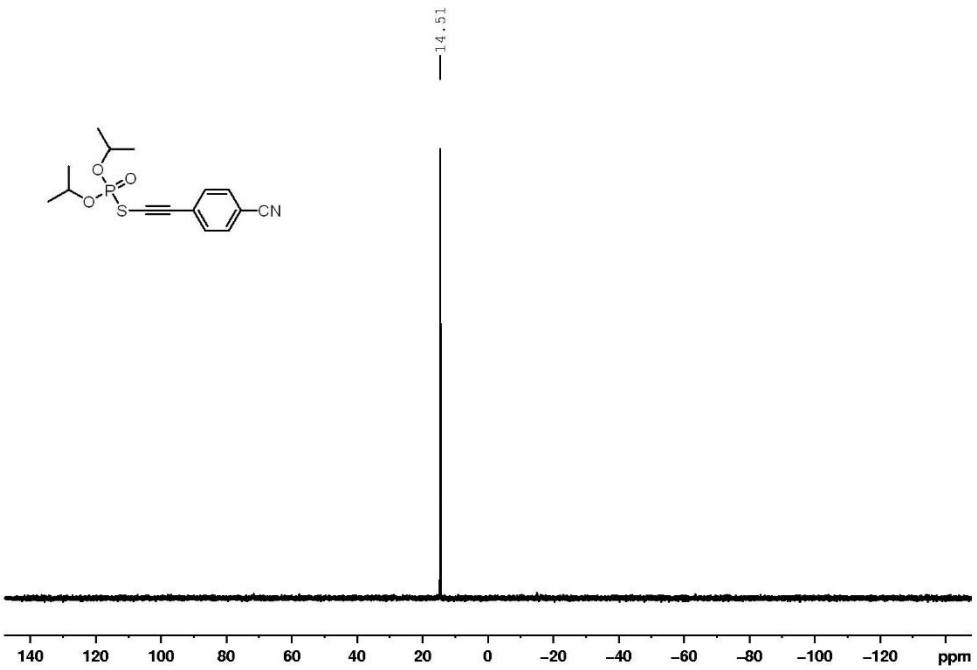
29


131.95
131.93
131.82
130.62
130.39
130.17
126.62
126.48
125.50
125.48
124.81
123.01
121.20
90.85
90.79
77.37
76.95
74.93
74.88
74.28
74.20
23.98
23.96
23.65
23.61
OPr-i
OPr-i
F3C
S
P
O
126.617
126.480
125.505
125.478
124.811
123.007
121.204
126 124 122 ppm
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

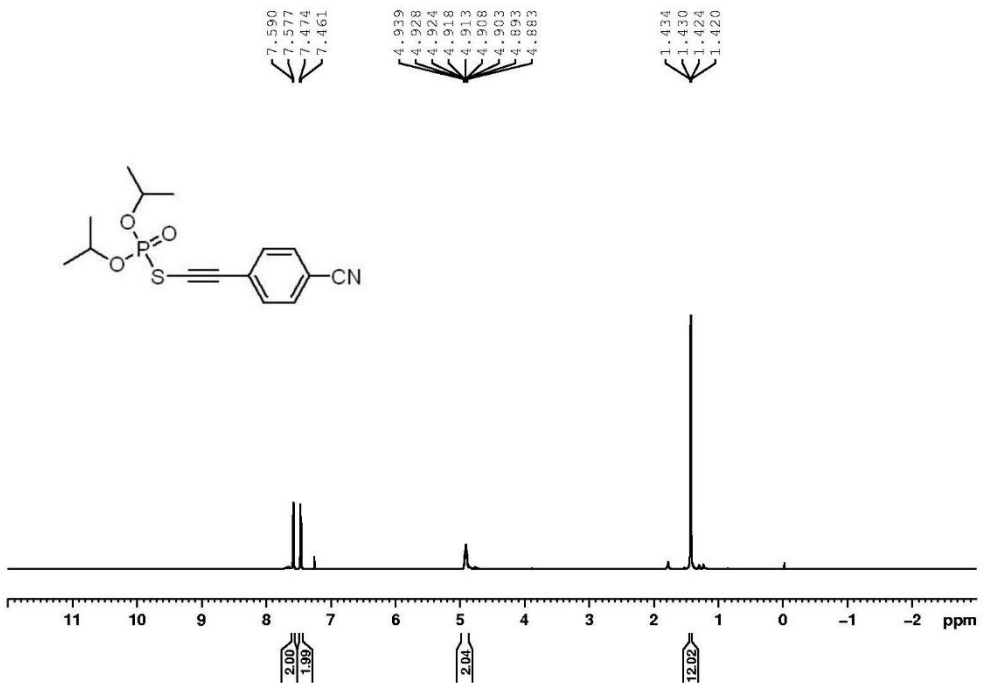
29


-62.92
OPr-i
OPr-i
F3C
S
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
ppm

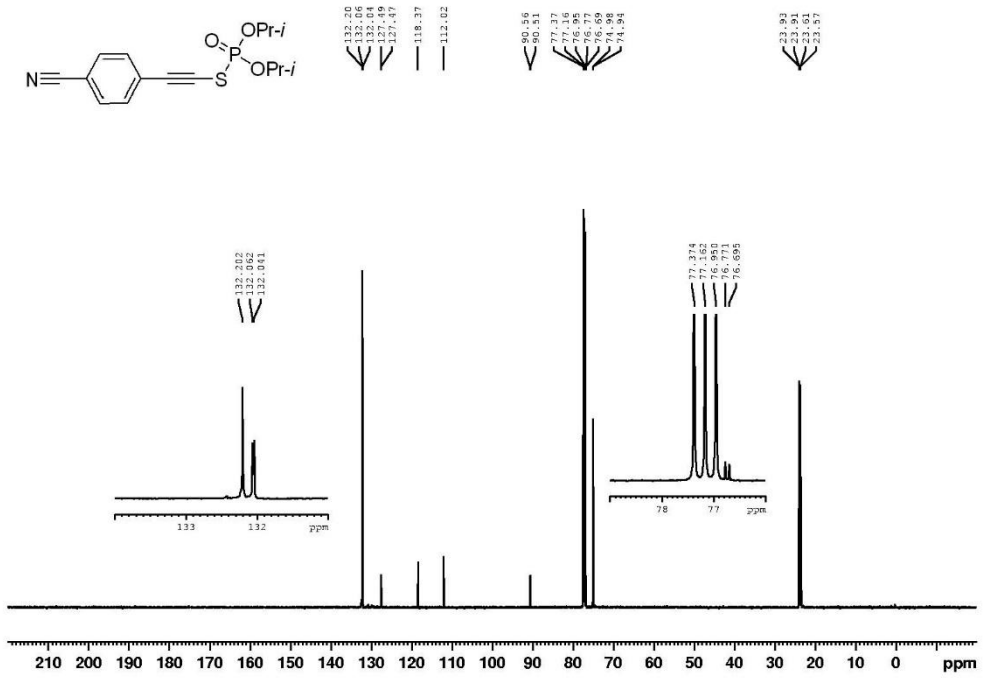
30


14.51
O
O
P
O
S
CN
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

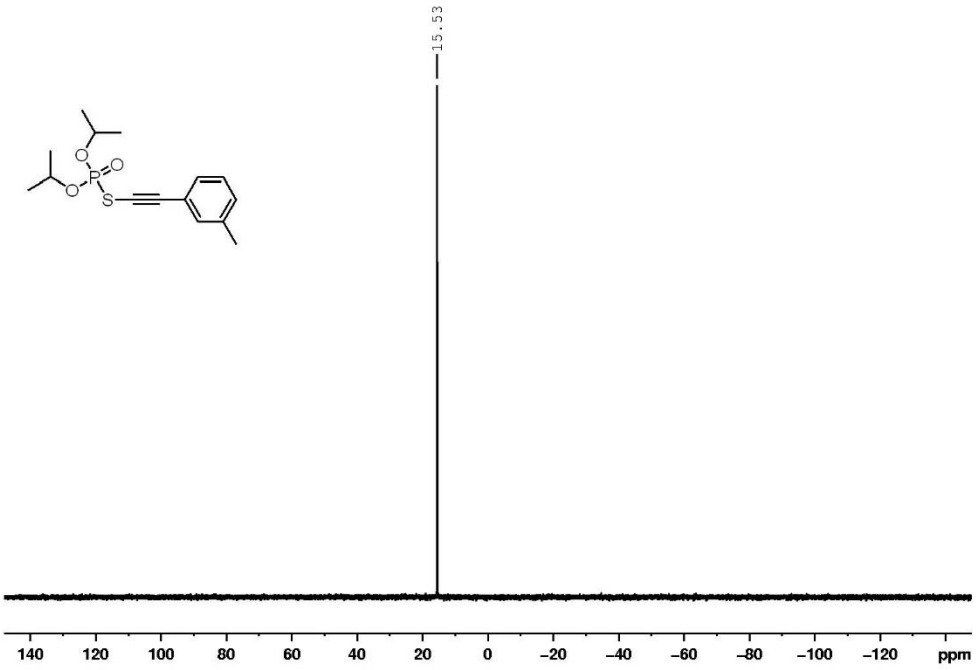
30


7.590
7.577
7.474
7.461
4.939
4.928
4.924
4.918
4.913
4.908
4.903
4.893
4.883
1.434
1.430
1.424
1.420
CN
11 10 9 8 7 6 5 4 3 2 1 0 −1 −2 ppm
2.00
1.99
2.04
12.02

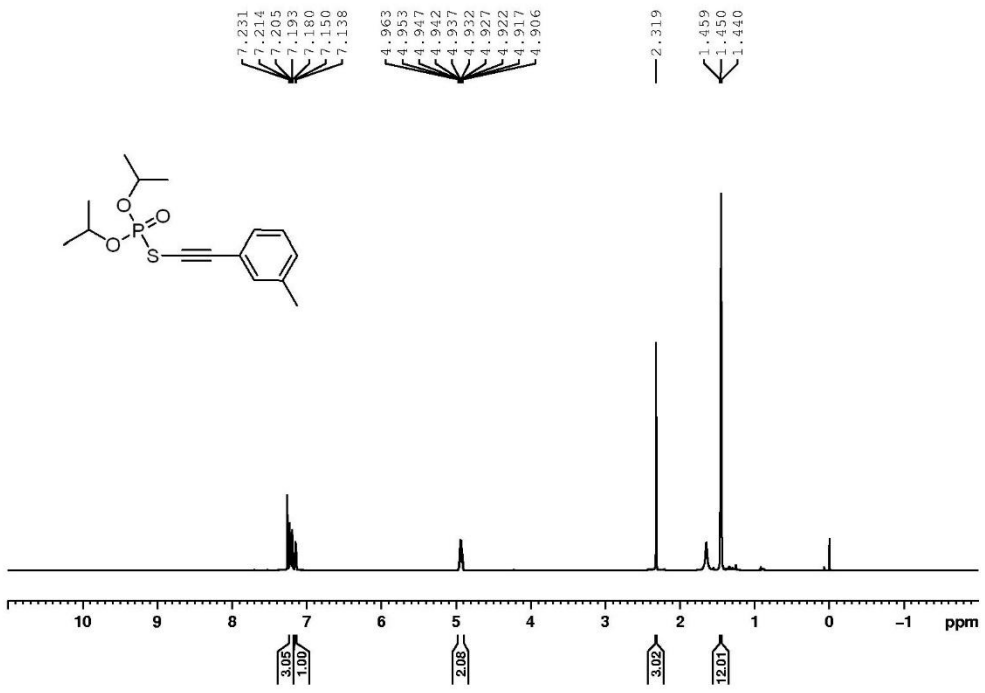
30


OPr-i
OPr-i
N
133.20
132.06
132.04
127.49
127.47
118.37
112.02
90.56
90.51
77.37
77.16
76.95
76.77
76.59
76.38
74.94
23.93
23.91
23.61
23.57
132.202
132.062
132.041
77.374
77.162
76.950
76.771
76.695
133 132 ppm
78 77 ppm
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

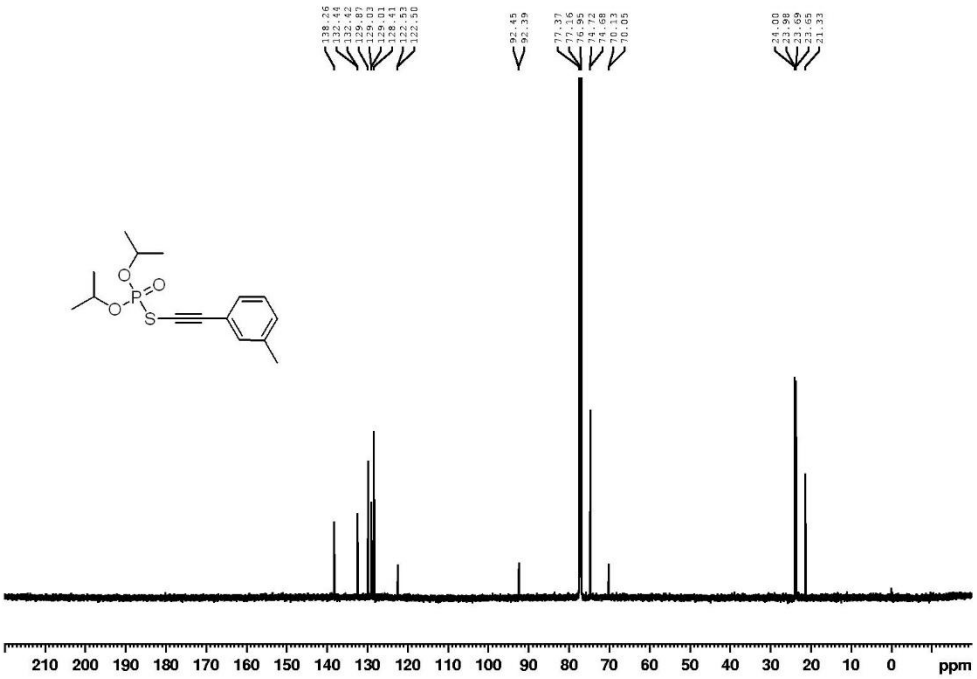
32


15.53
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

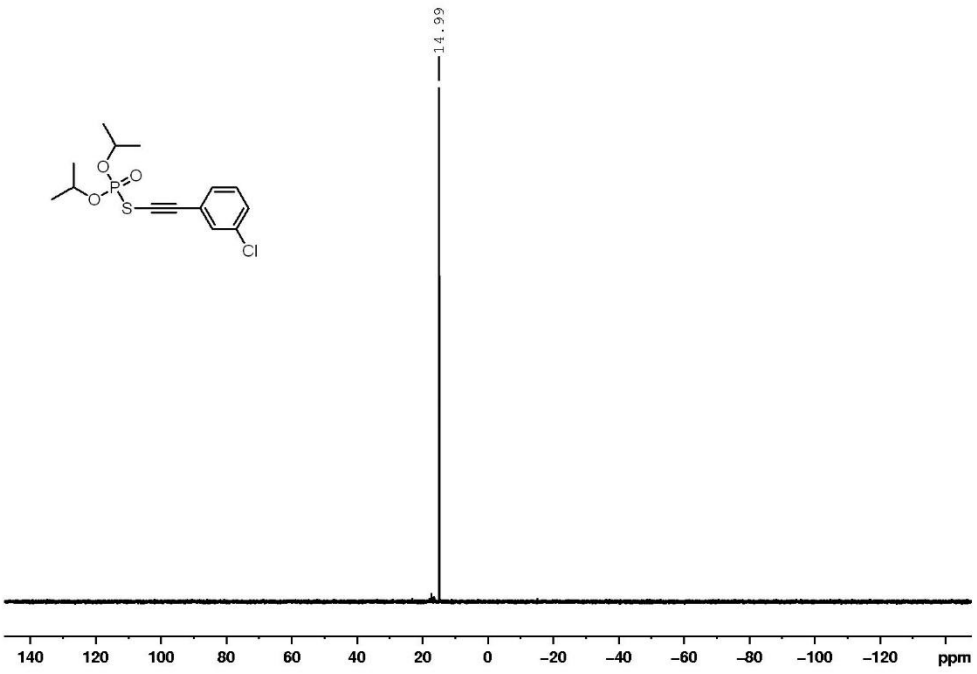
32


7.231
7.214
7.205
7.193
7.180
7.150
7.138
4.963
4.953
4.947
4.942
4.937
4.932
4.927
4.922
4.917
4.906
2.319
1.459
1.450
1.440
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
3.05
1.00
2.08
3.02
12.01

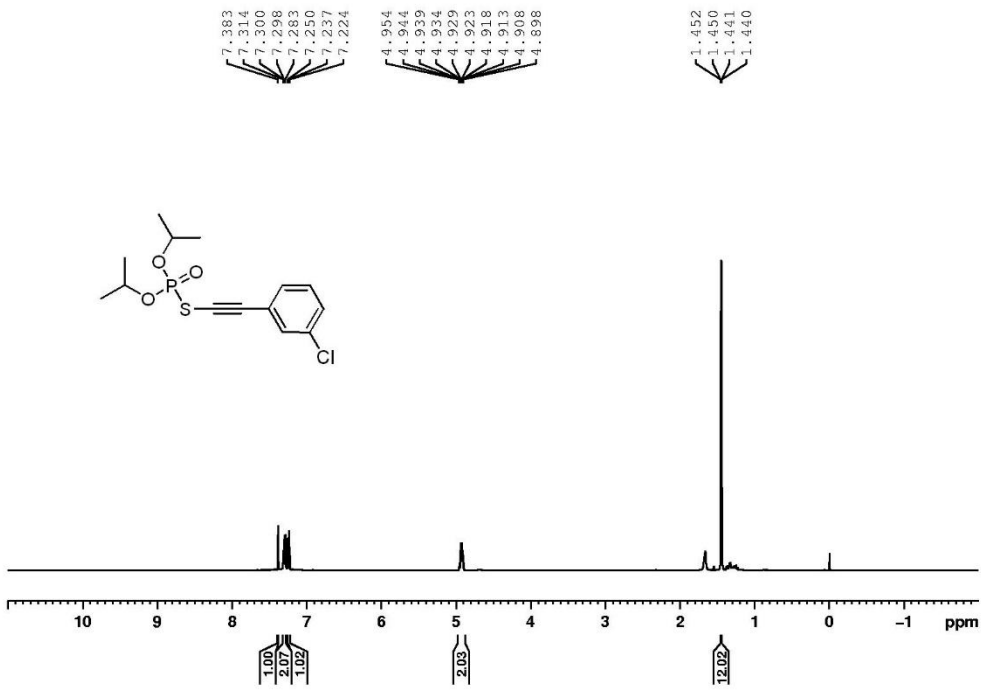
32


138.26
132.46
132.02
129.87
129.03
129.01
128.41
122.53
122.50
92.45
92.39
77.37
77.16
76.95
74.72
74.68
70.13
70.05
24.00
23.98
23.69
23.65
21.33
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

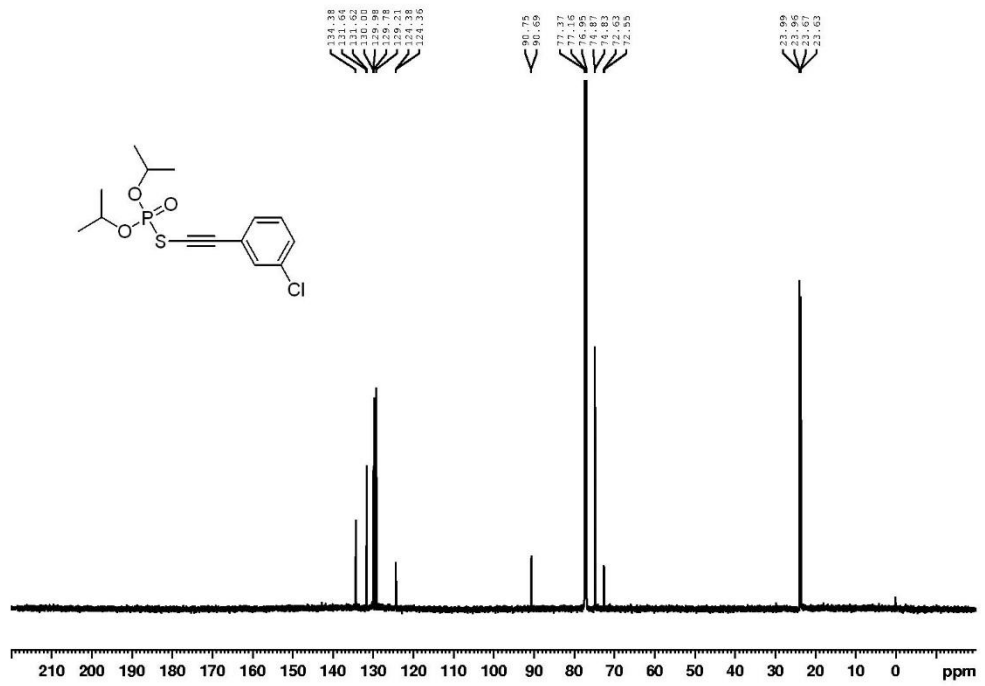
33


14.99
Cl
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

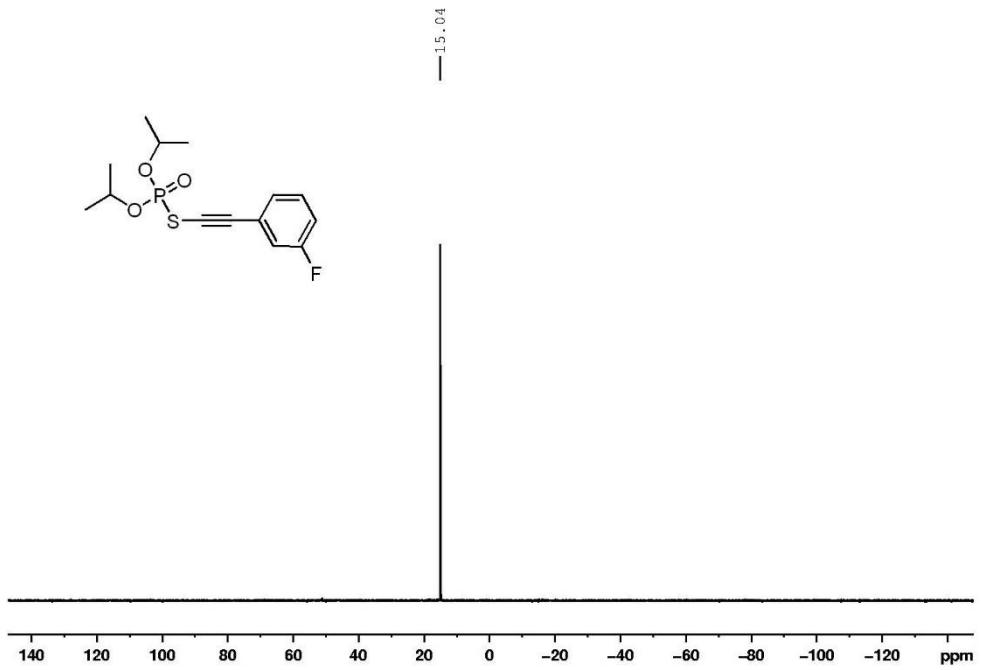
33


7.383
7.314
7.300
7.298
7.283
7.250
7.237
7.224
4.954
4.944
4.939
4.934
4.929
4.923
4.918
4.913
4.908
4.898
1.452
1.450
1.441
1.440
Cl
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
1.00
2.07
1.02
2.03
12.02

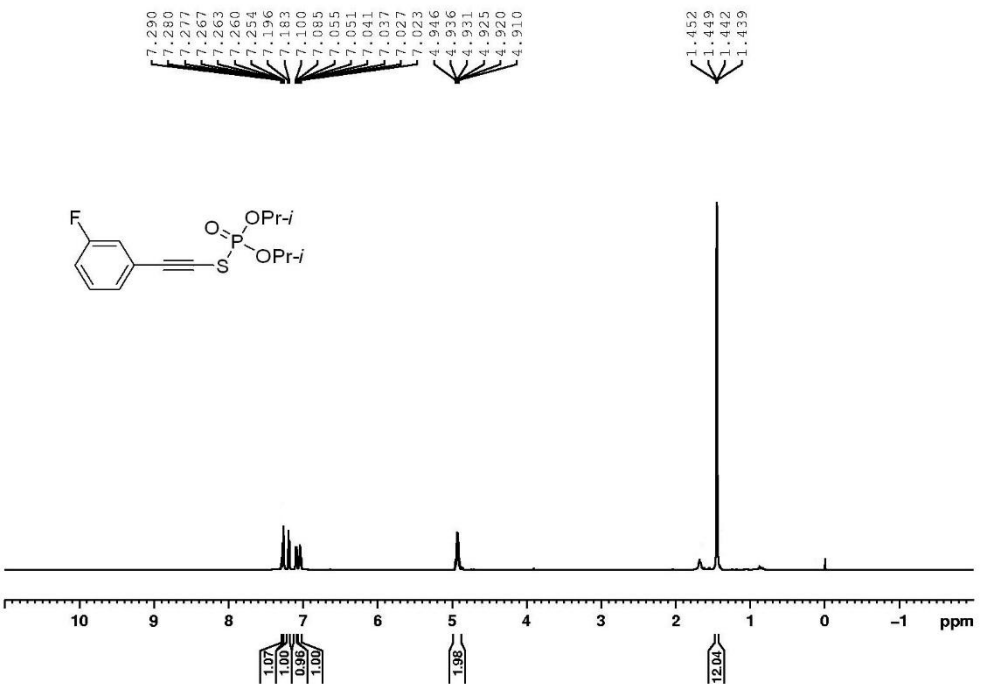
33


134.38
131.86
131.62
130.00
129.98
129.78
129.21
124.38
124.36
90.75
90.69
77.37
77.16
76.95
76.87
74.83
72.63
72.55
23.99
23.96
23.67
23.63
Cl
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

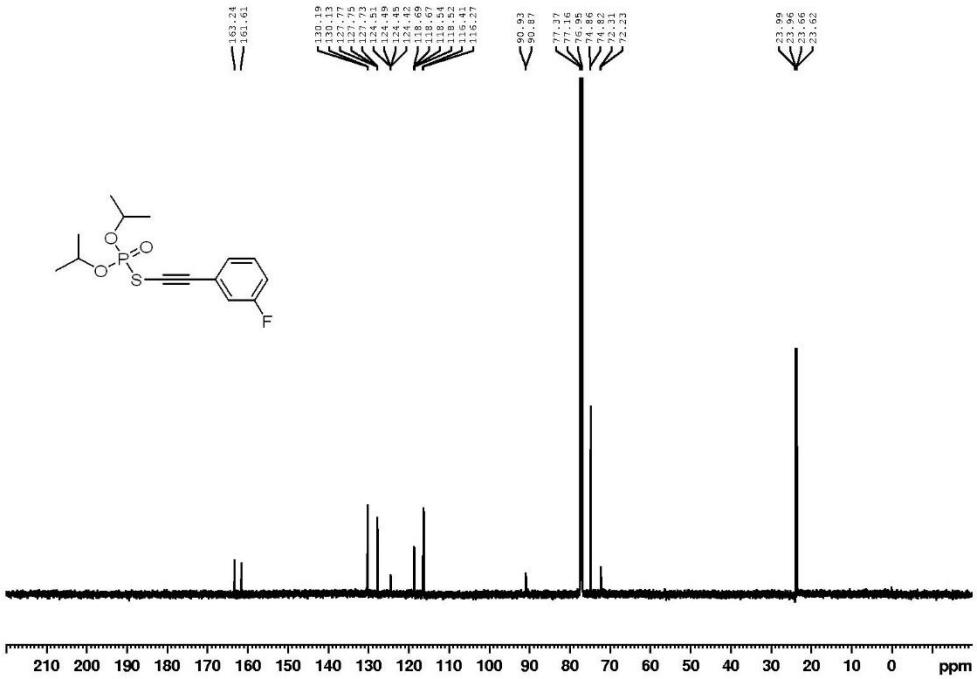
34


15.04
O
P
O
S
F
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

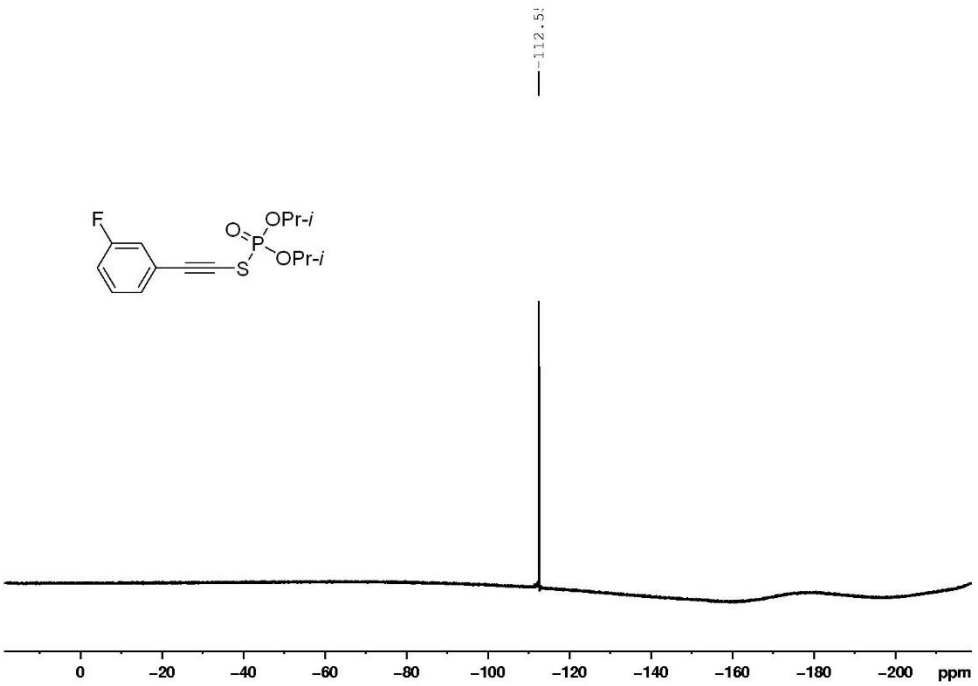
34


7.290
7.280
7.277
7.267
7.263
7.260
7.254
7.196
7.183
7.100
7.085
7.055
7.051
7.041
7.037
7.027
7.023
4.946
4.936
4.931
4.925
4.920
4.910
1.452
1.449
1.442
1.439
F
O
P
OPr-i
OPr-i
S
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
1.07
1.00
0.96
1.00
1.98
12.04

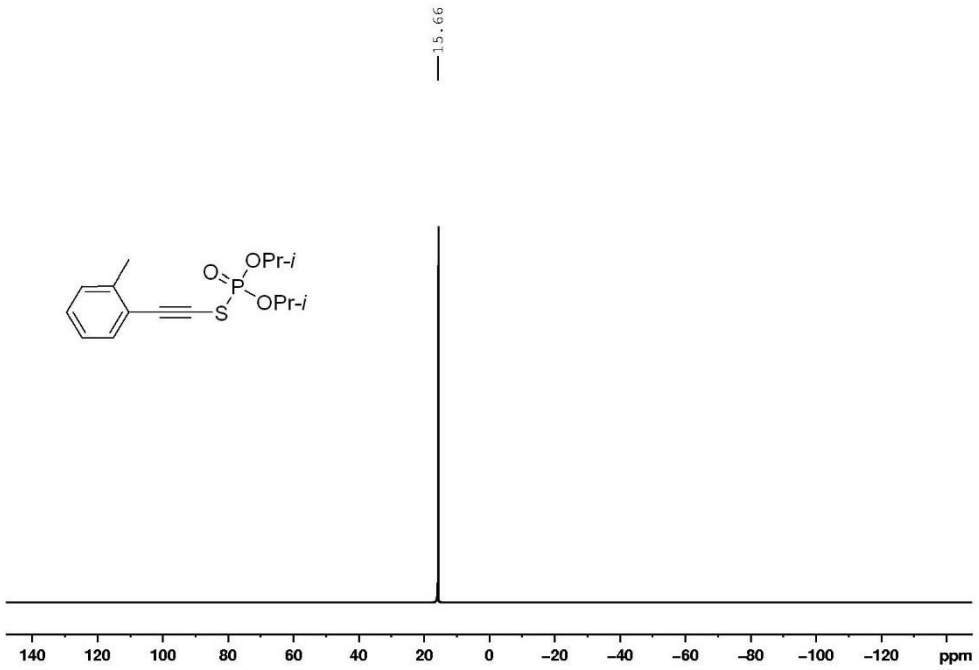
34


163.24
161.61
130.19
130.13
127.77
127.75
127.73
124.51
124.49
124.45
124.42
118.69
118.67
118.54
118.52
116.41
116.27
90.93
90.87
77.37
77.16
76.95
74.86
74.82
72.31
72.23
23.99
23.96
23.66
23.62
F
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

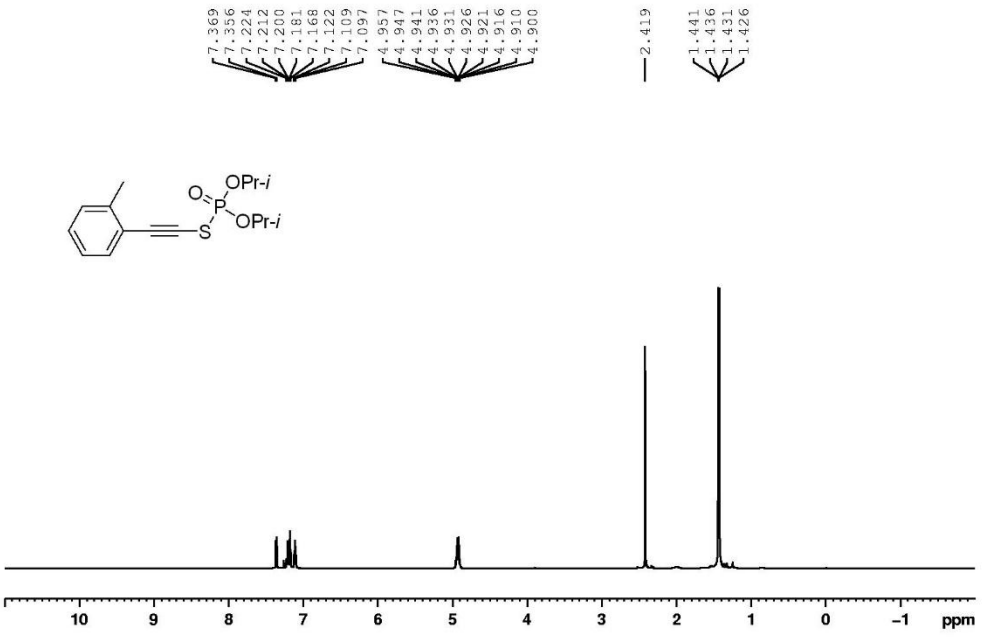
34


-112.51
F
OPr-i
OPr-i
0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 ppm

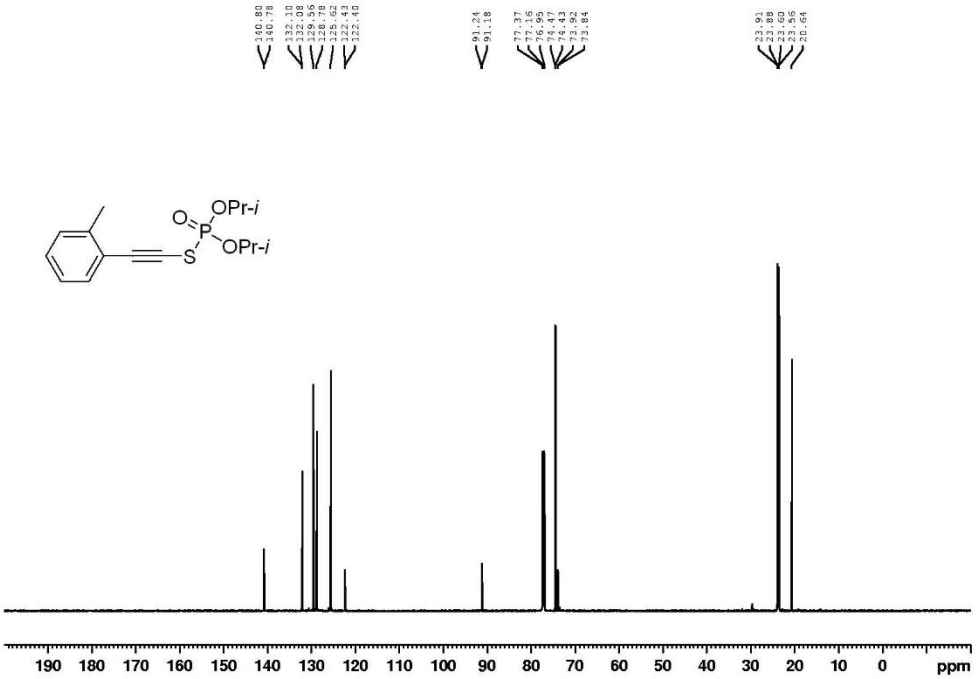
35


15.66
OPr-i
OPr-i
O
P
S
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

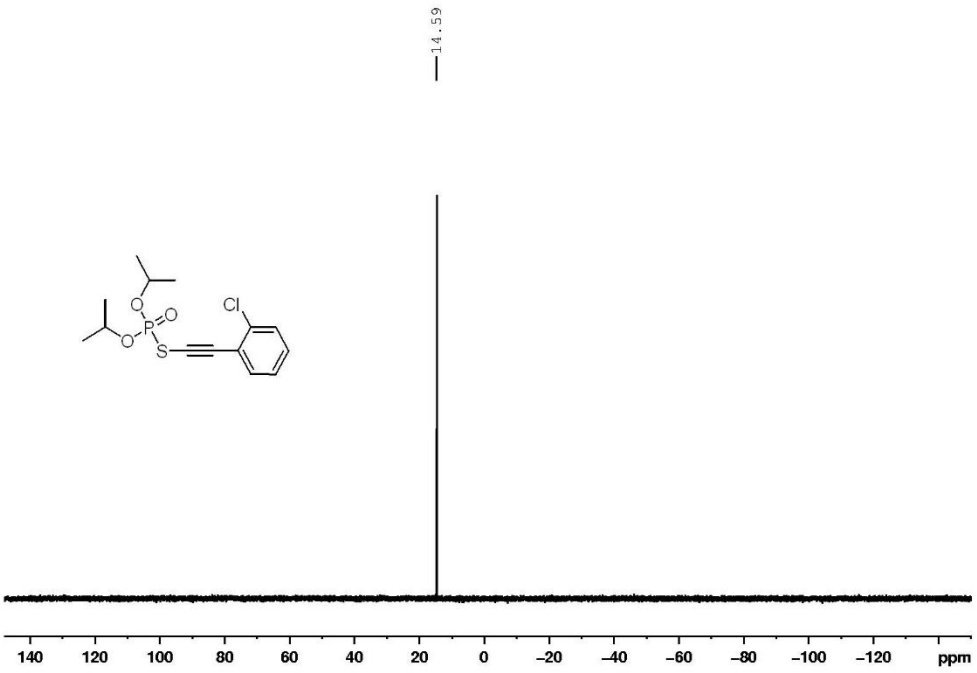
35


7.369
7.356
7.224
7.212
7.200
7.181
7.168
7.122
7.109
7.097
4.957
4.947
4.941
4.936
4.931
4.926
4.921
4.916
4.910
4.900
2.419
1.441
1.436
1.431
1.426
OPr-i
OPr-i
O
P
S
10
9
8
7
6
5
4
3
2
1
0
-1
ppm

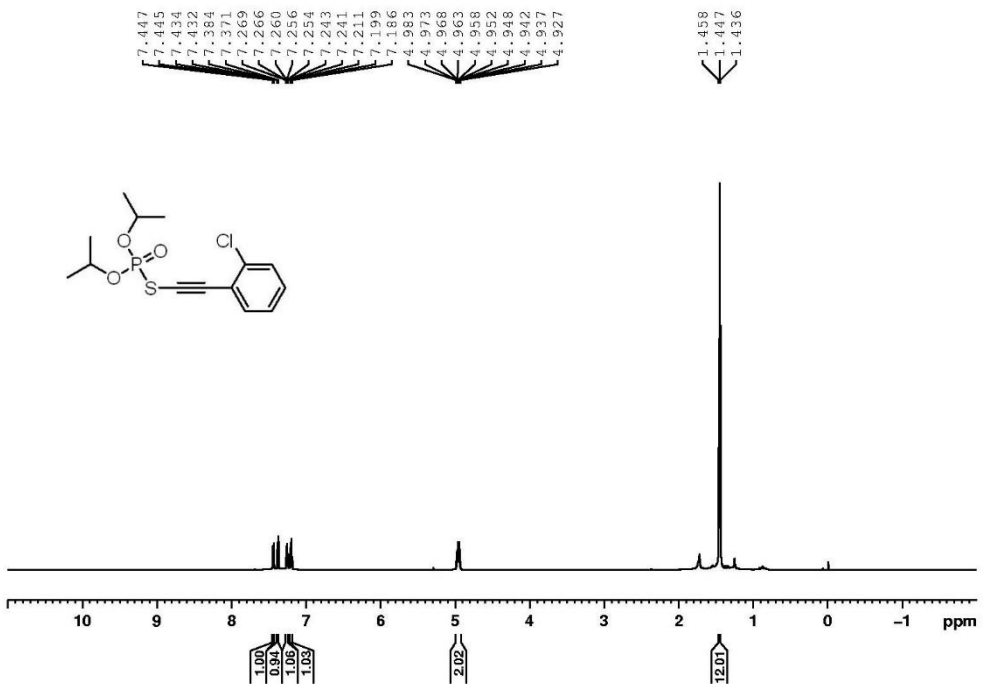
35


OPr-i
OPr-i
O
P
S
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

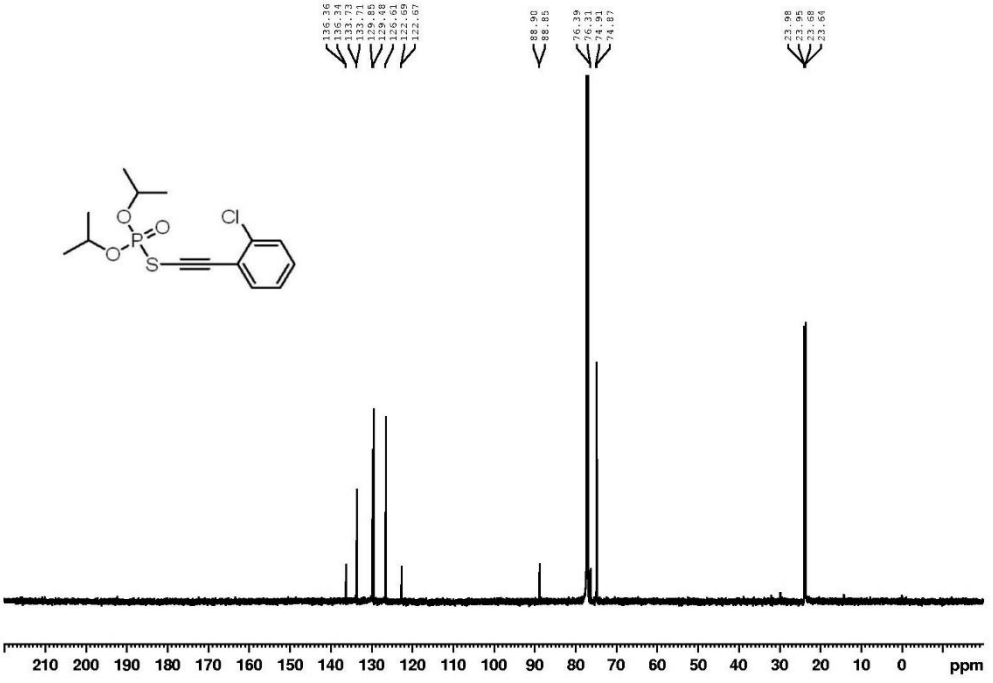
36


14.59
O
O
P
O
S
Cl
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

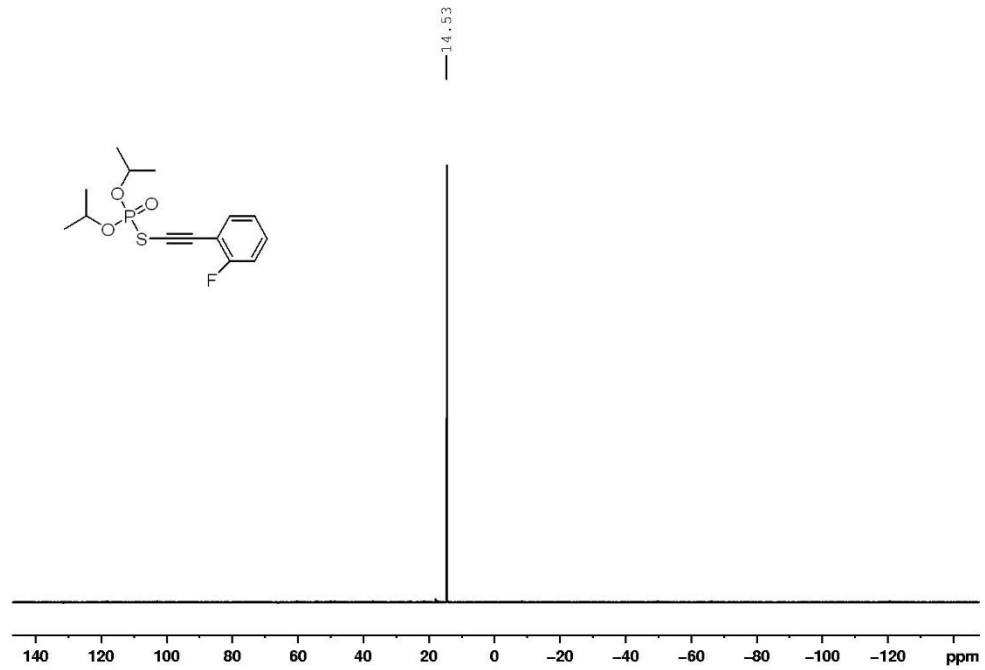
36


7.447
7.445
7.434
7.432
7.384
7.371
7.269
7.266
7.260
7.256
7.254
7.243
7.241
7.211
7.199
7.186
4.983
4.973
4.968
4.963
4.958
4.952
4.948
4.942
4.937
4.927
1.458
1.447
1.436
Cl
O
P
O
O
S
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
1.00
0.94
1.06
1.03
2.02
12.01

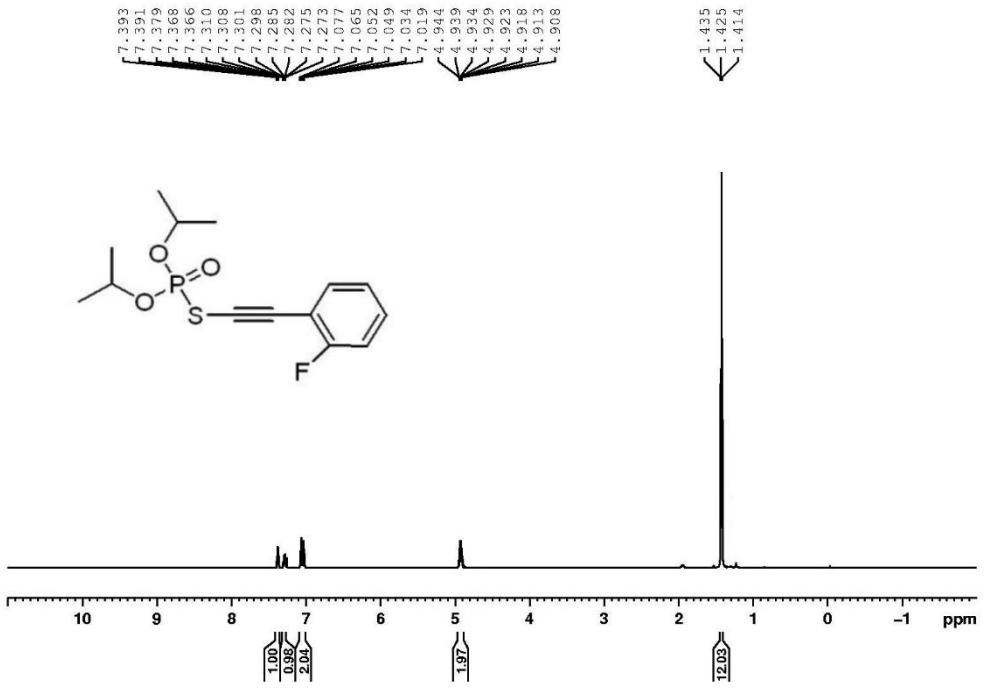
36


136.36
136.34
133.73
133.71
129.85
129.48
129.01
122.69
122.67
88.90
88.85
76.39
76.31
74.91
74.87
23.98
23.95
23.68
23.64
Cl
O
P
O
O
S
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

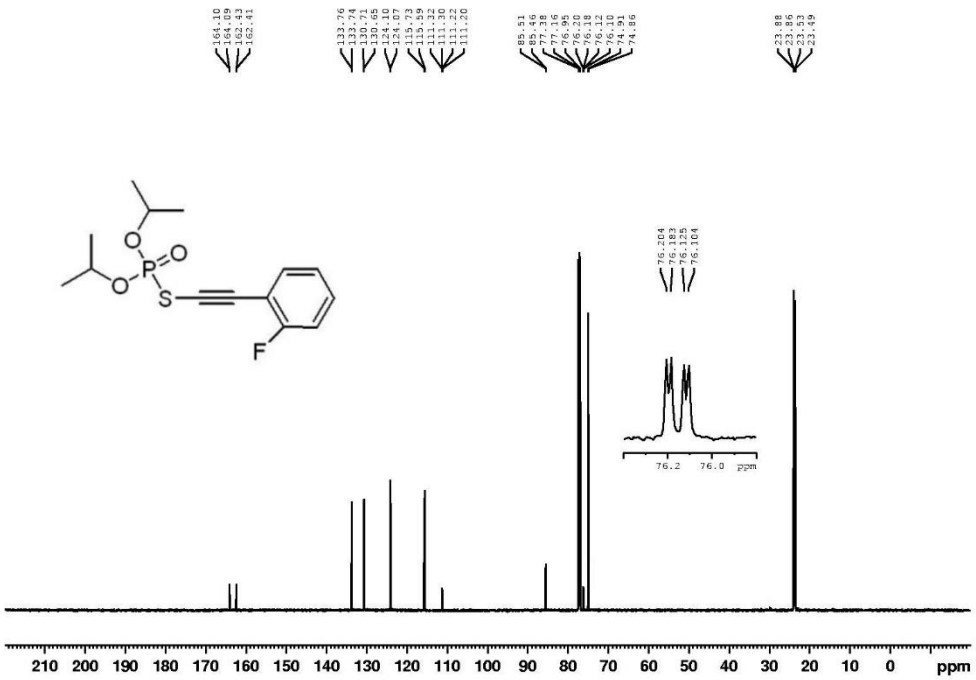
37


14.53
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

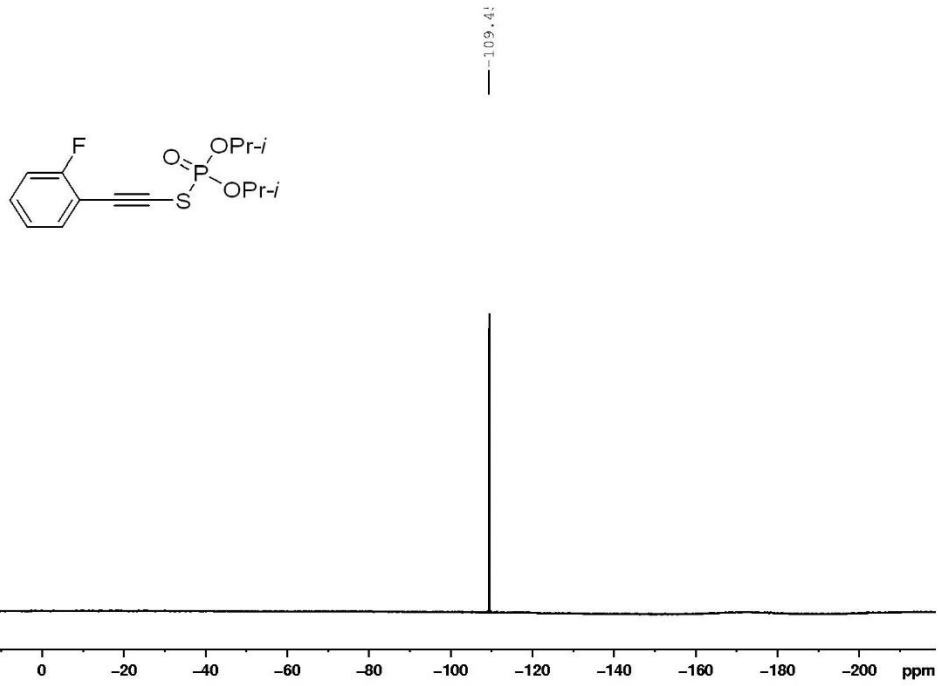
37


7.393
7.391
7.379
7.368
7.366
7.310
7.308
7.301
7.298
7.285
7.282
7.275
7.273
7.077
7.065
7.052
7.049
7.034
7.019
4.944
4.939
4.934
4.929
4.923
4.918
4.913
4.908
1.435
1.425
1.414
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
1.00
0.98
2.04
1.97
12.03

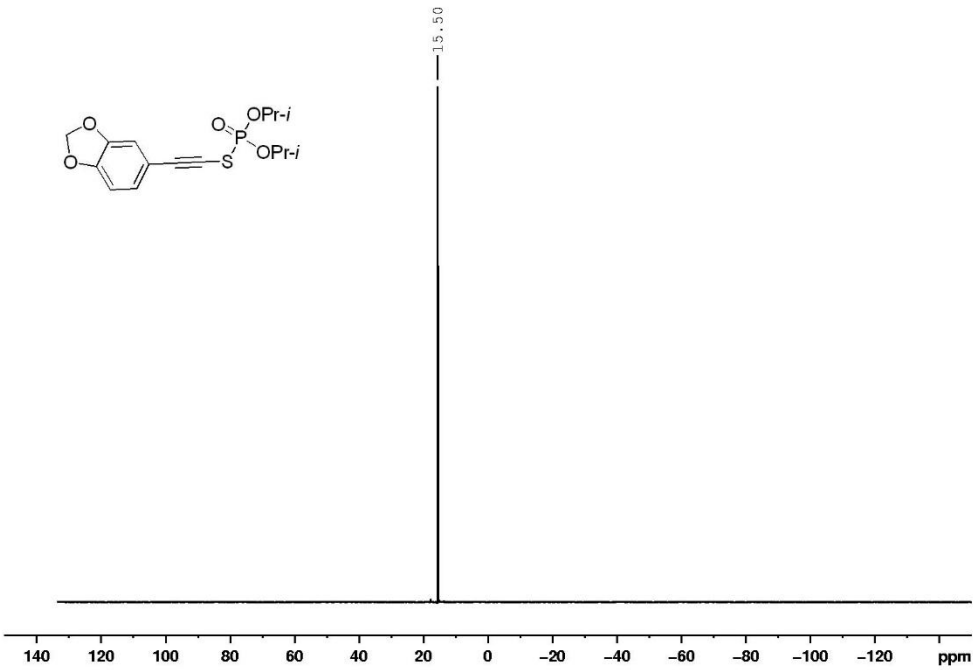
37


164.10
164.09
162.43
162.41
133.76
133.74
130.71
130.65
124.10
124.07
115.73
115.49
111.32
111.30
111.22
111.20
85.51
85.45
77.38
77.16
76.95
76.70
76.18
76.12
76.10
74.91
74.86
23.88
23.86
23.53
23.49
76.204
76.183
76.125
76.104
76.2
76.0
ppm
F
O
P
S
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

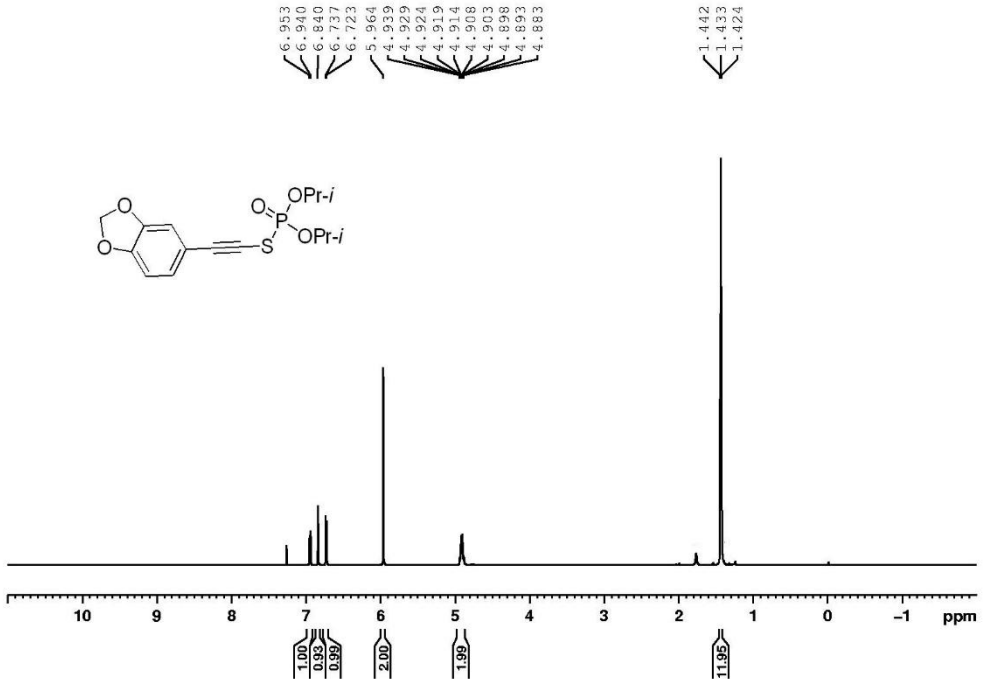
37


-109.41
F
OPr-i
OPr-i
O
P
S
0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 ppm

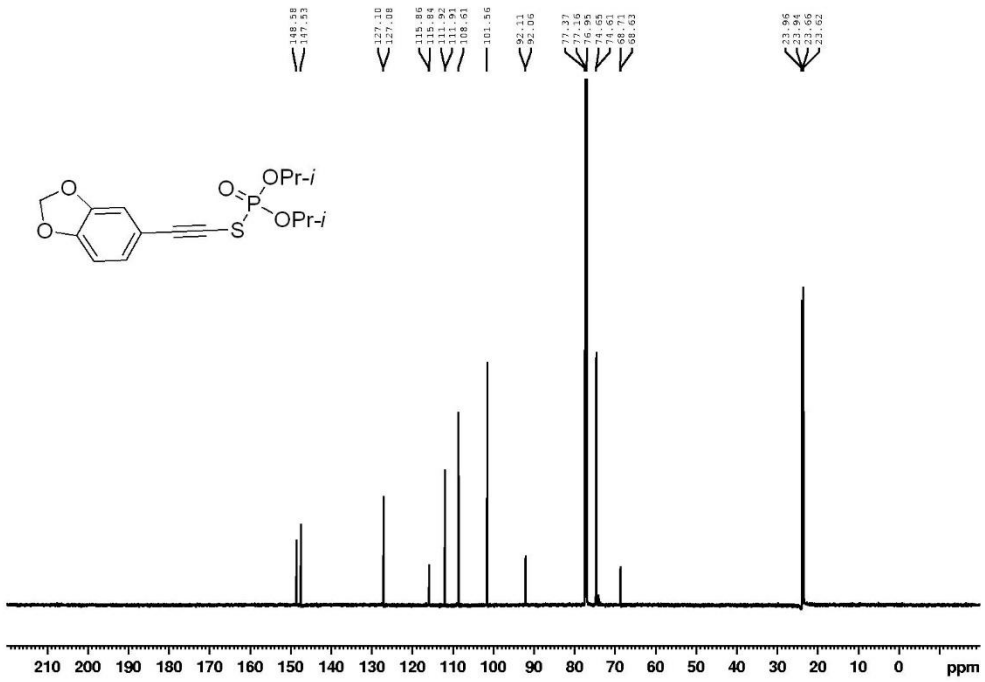
38


15.50
OPr-i
OPr-i
O
P
S
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

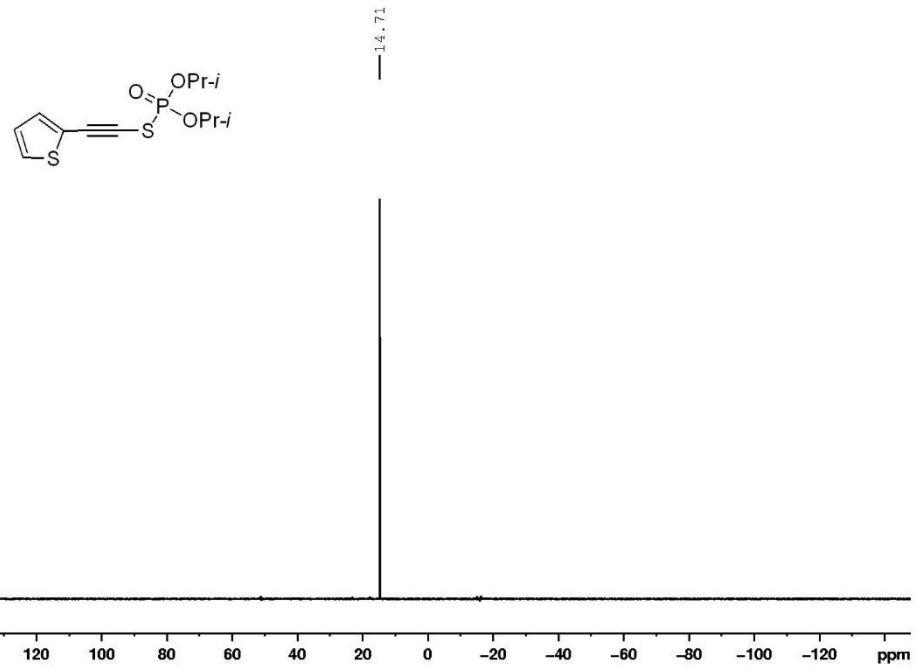
38


6.953
6.840
6.840
6.737
6.723
5.964
4.939
4.929
4.924
4.919
4.914
4.908
4.903
4.898
4.893
4.883
1.442
1.433
1.424
OPr-i
OPr-i
O
P
S
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
1.00
0.93
0.99
2.00
1.99
11.95

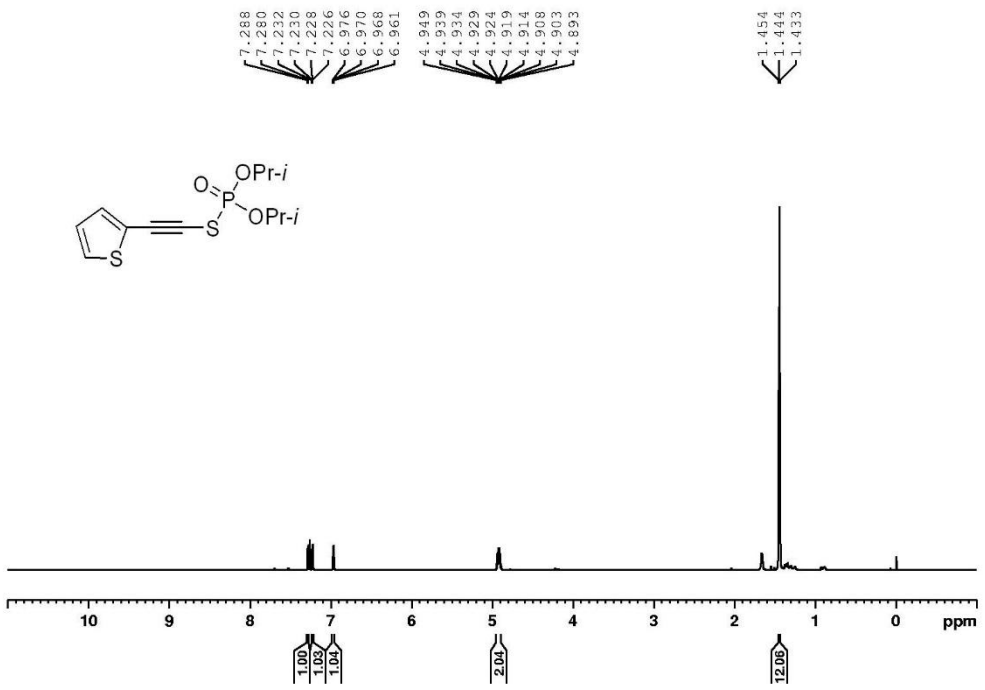
38


148.58
147.53
127.10
127.08
115.86
115.84
111.92
111.91
108.61
101.56
92.11
92.06
77.37
77.16
76.95
74.65
73.61
68.71
68.63
23.96
23.94
23.66
23.62
OPr-i
OPr-i
O
O
O
P
S
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

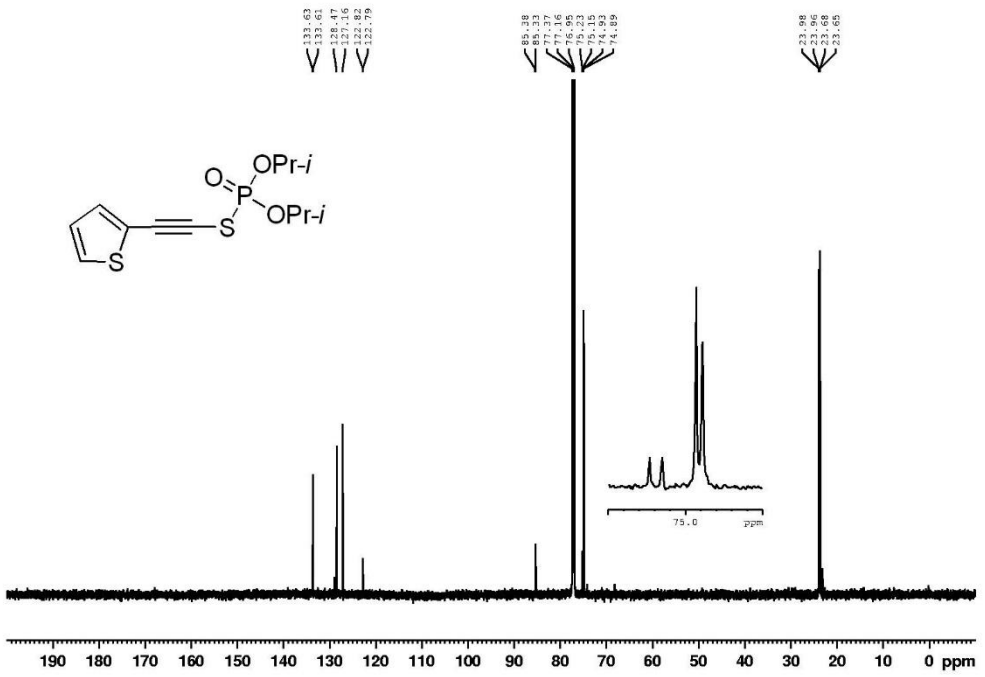
39


14.71
OPr-i
OPr-i
O
P
S
S
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

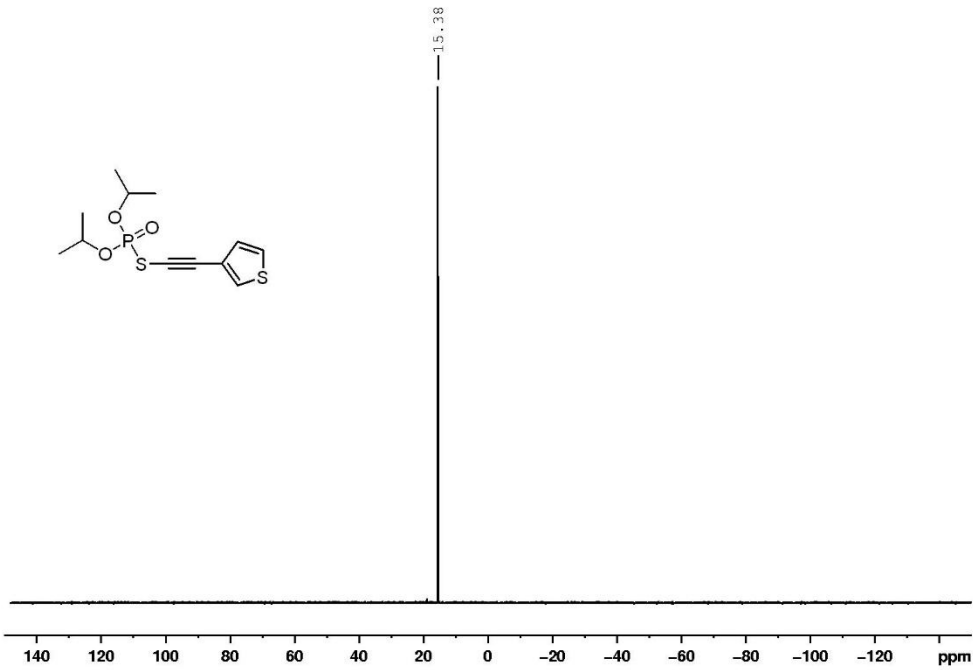
39


7.288
7.280
7.232
7.230
7.228
7.226
6.976
6.970
6.968
6.961
4.949
4.939
4.934
4.929
4.924
4.919
4.914
4.908
4.903
4.893
1.454
1.444
1.433
OPr-i
OPr-i
10 9 8 7 6 5 4 3 2 1 0 ppm
1.00
1.03
1.04
2.04
12.06

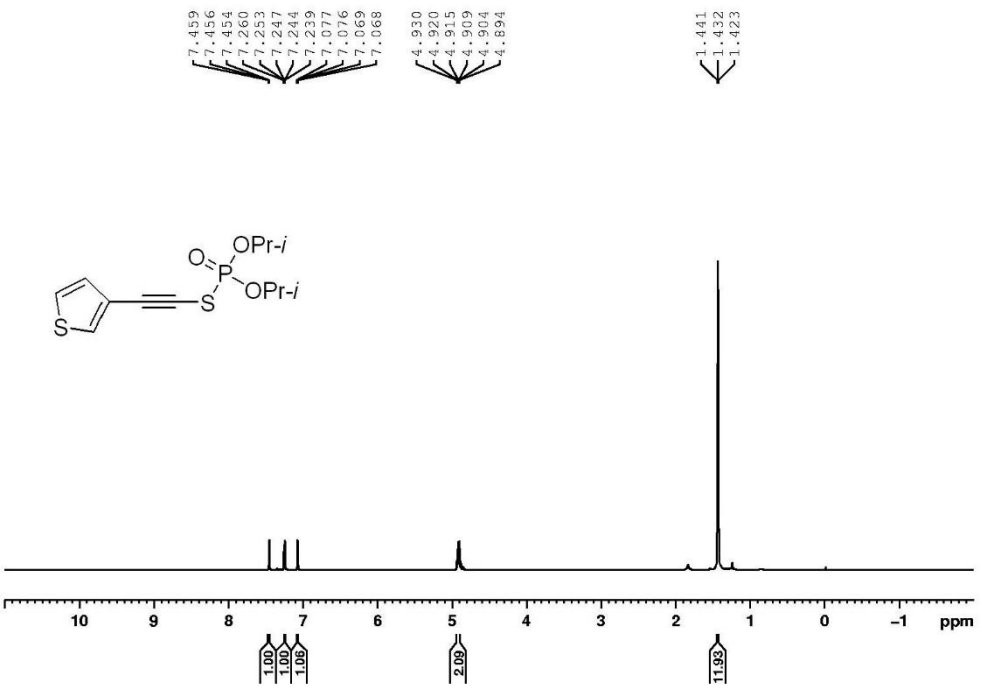
39


133.63
133.61
128.47
127.16
122.80
122.79
85.38
85.33
77.37
77.16
76.95
76.73
75.15
74.93
74.89
23.98
23.96
23.68
23.65
OPr-i
OPr-i
75.0 ppm
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

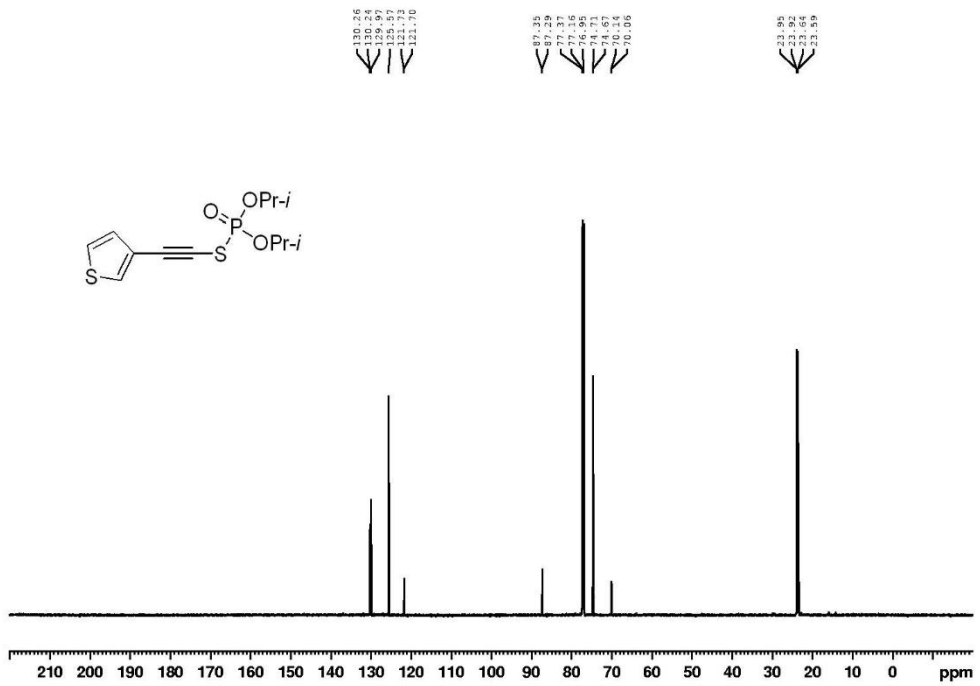
40


15.38
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

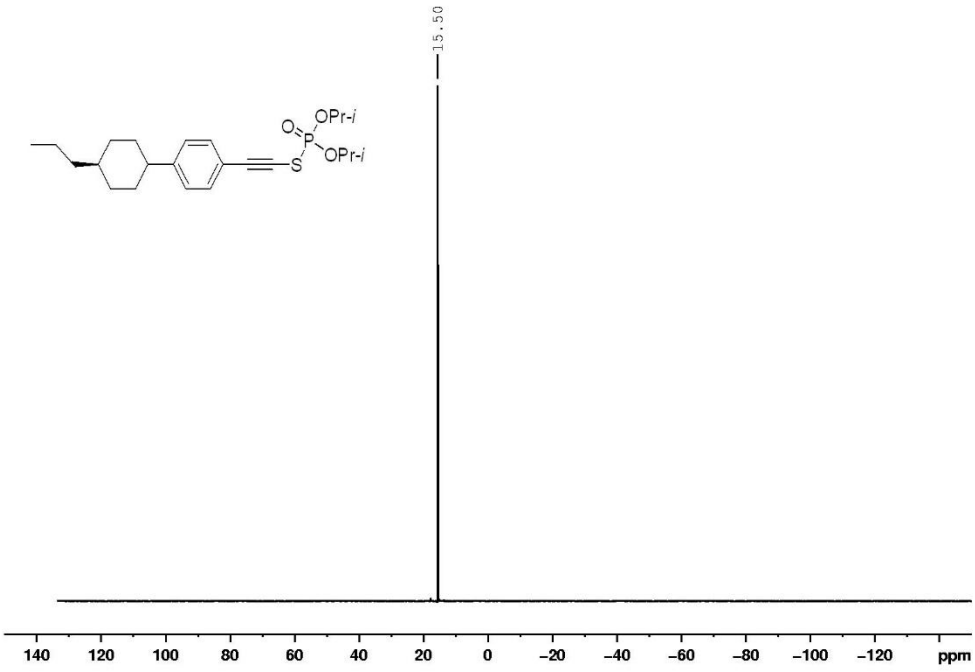
40


7.459
7.456
7.454
7.260
7.253
7.247
7.244
7.239
7.077
7.076
7.069
7.068
4.930
4.920
4.915
4.909
4.904
4.894
1.441
1.432
1.423
OPr-i
OPr-i
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
1.00
1.00
1.06
2.09
11.93

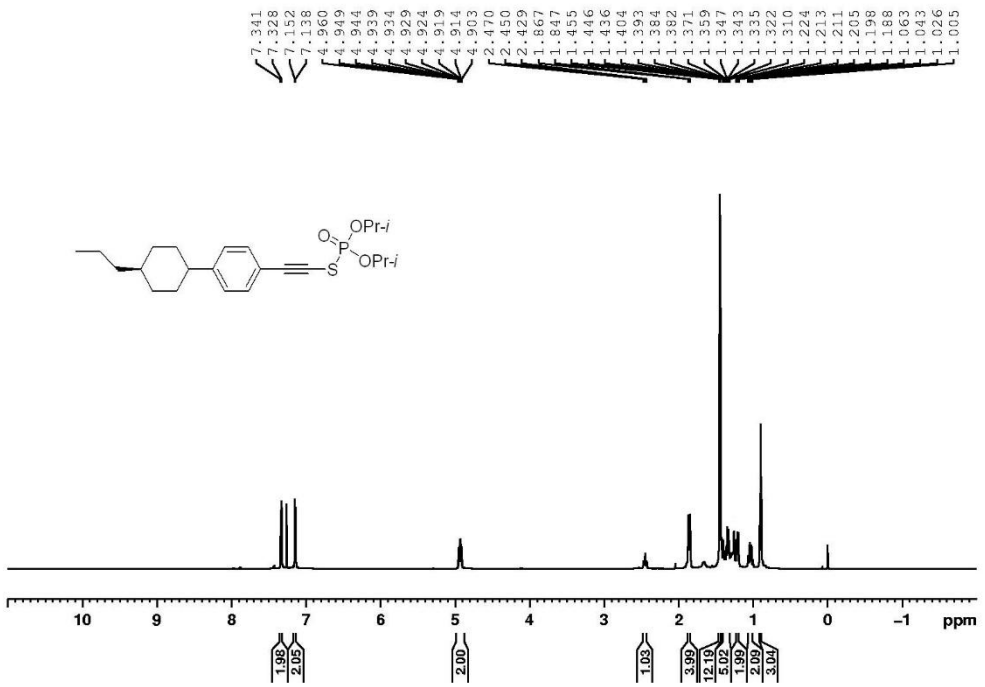
40


130.26
130.24
129.97
125.57
122.73
121.70
87.35
87.29
77.37
77.16
76.96
74.71
74.67
70.14
70.06
23.95
23.82
23.64
23.59
OPr-i
OPr-i
S
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

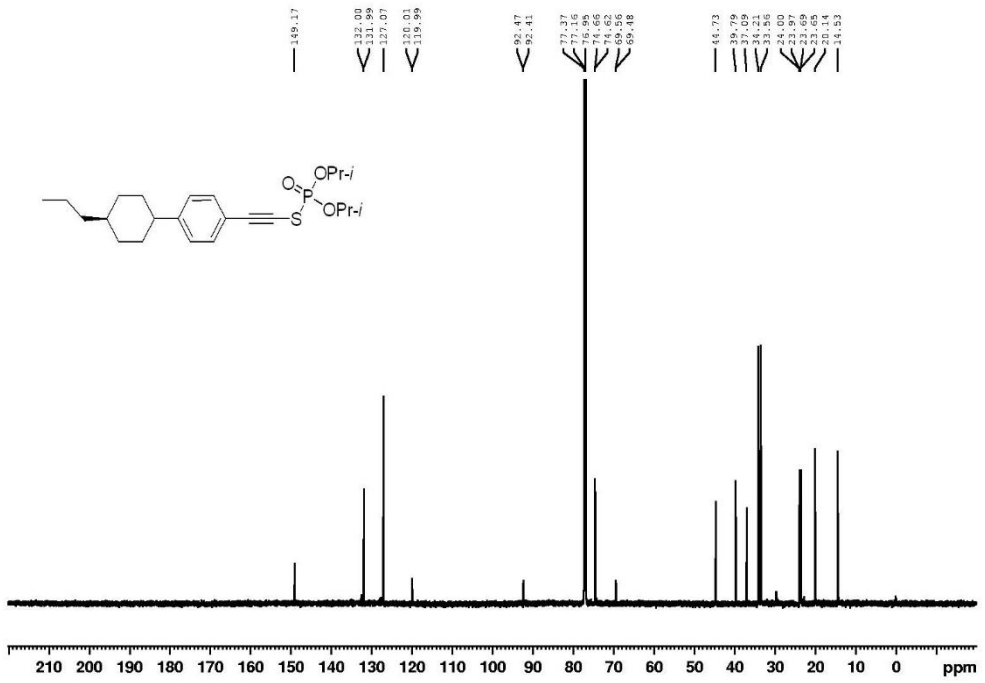
42


15.50
OPr-i
OPr-i
S
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

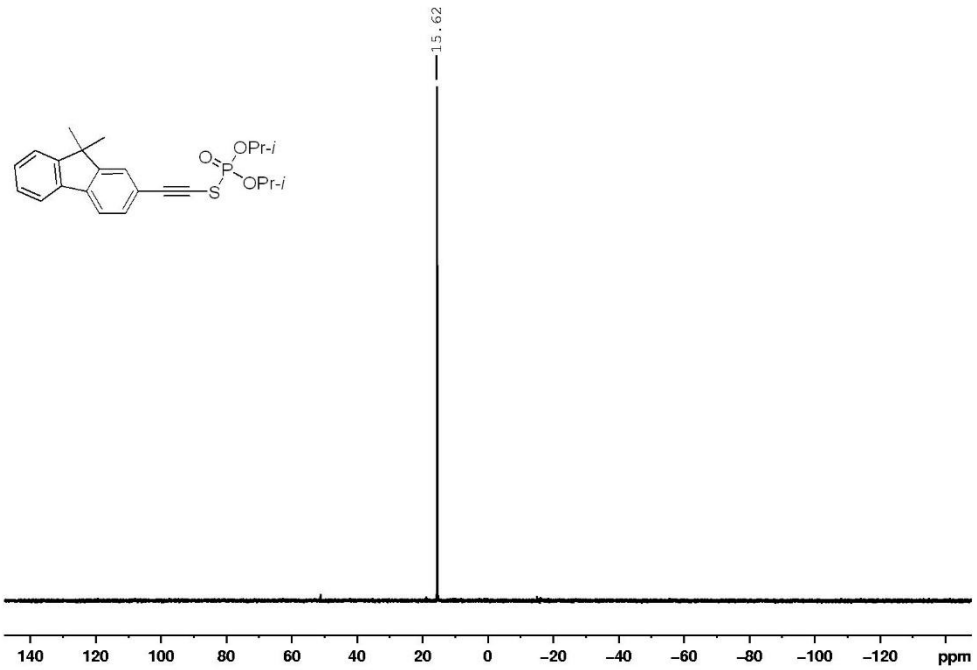
42


7.341
7.328
7.152
7.138
4.960
4.949
4.944
4.939
4.934
4.929
4.924
4.919
4.914
4.903
2.470
2.450
2.429
1.867
1.847
1.455
1.446
1.436
1.404
1.393
1.384
1.382
1.371
1.359
1.347
1.343
1.335
1.322
1.310
1.224
1.213
1.211
1.205
1.198
1.188
1.063
1.043
1.026
1.005
OPr-i
OPr-i
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
1.98
2.05
2.00
1.03
3.99
12.19
5.02
1.99
2.09
3.04

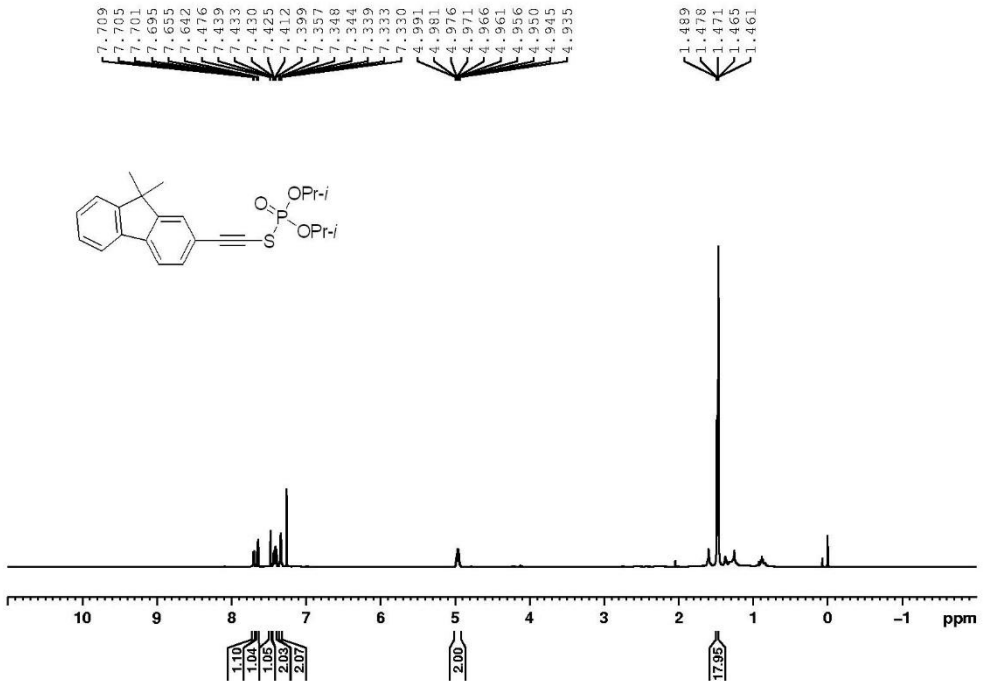
42


149.17
132.00
131.99
127.07
120.01
119.99
92.47
92.41
77.37
77.16
76.95
74.66
74.62
69.56
69.48
44.73
39.79
37.09
34.21
33.56
24.00
23.87
23.69
23.65
20.14
14.53
OPr-i
OPr-i
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

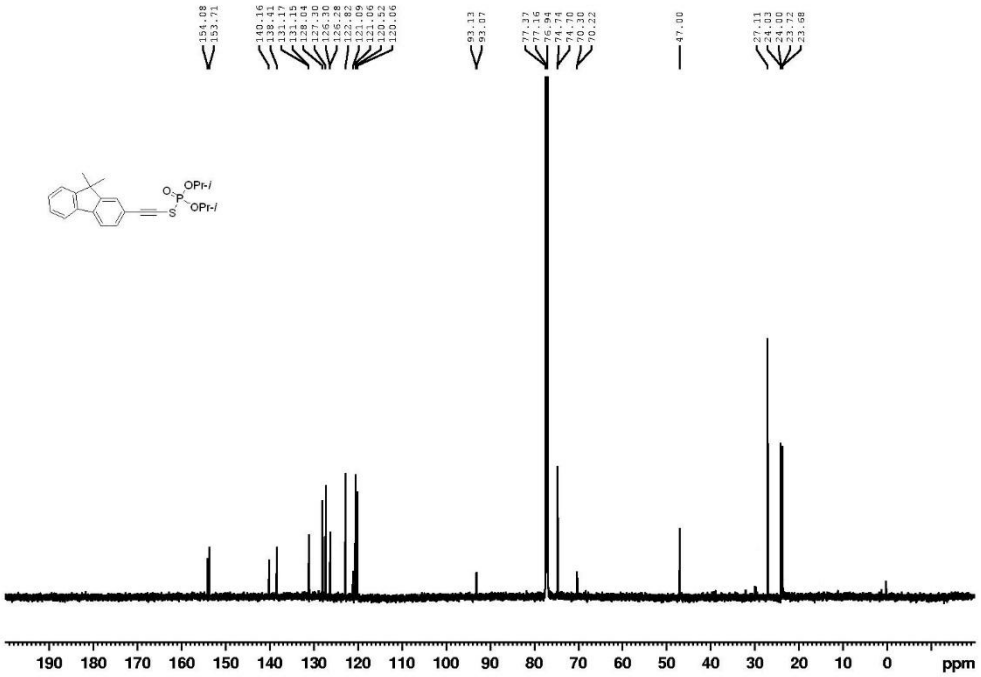
43


15.62
OPr-i
OPr-i
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

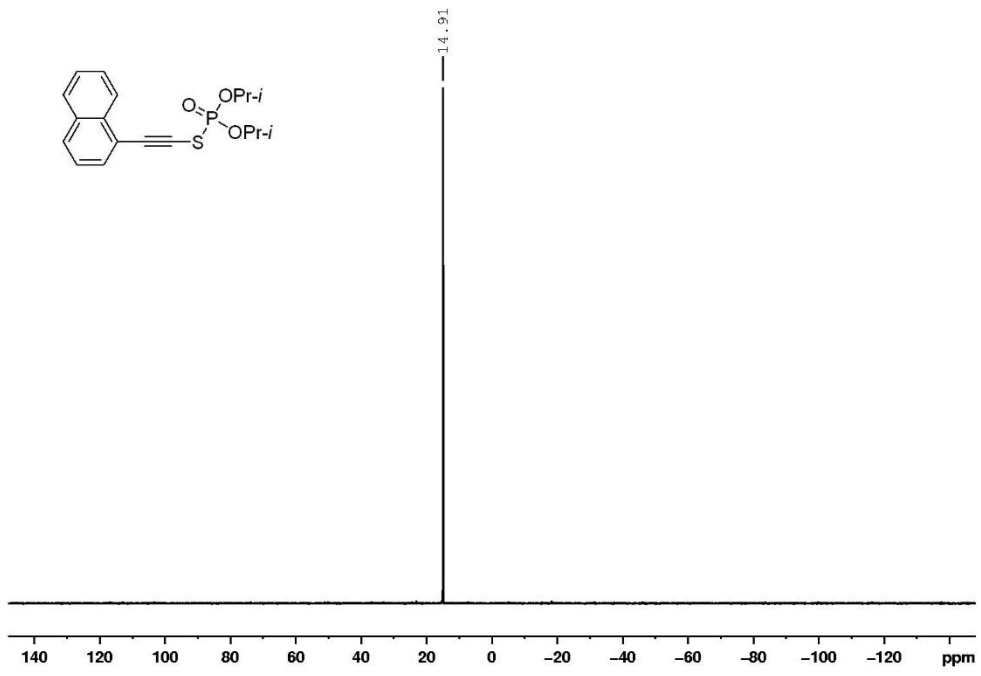
43


7.709
7.705
7.701
7.695
7.655
7.642
7.476
7.439
7.433
7.430
7.425
7.412
7.399
7.357
7.348
7.344
7.339
7.333
7.330
4.991
4.981
4.976
4.971
4.966
4.961
4.956
4.950
4.945
4.935
1.489
1.478
1.471
1.465
1.461
OPr-i
OPr-i
10 9 8 7 6 5 4 3 2 1 0 -1 ppm
1.10
1.04
1.05
2.03
2.07
2.00
17.95

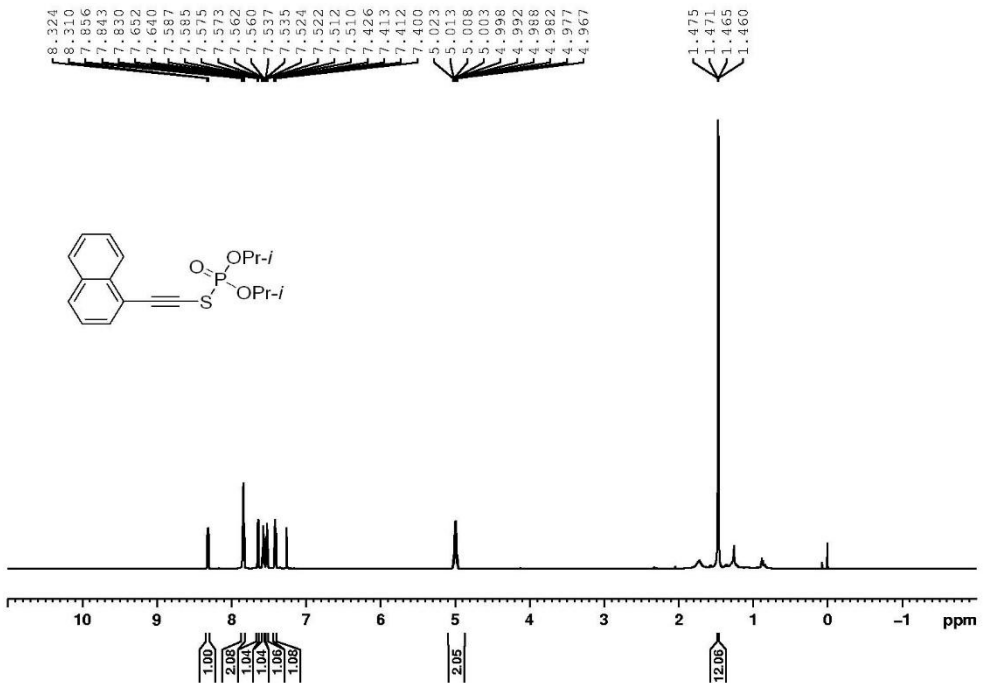
43


154.08
153.71
140.16
138.41
133.17
131.15
128.04
127.30
126.70
126.28
122.82
121.09
121.06
120.22
120.06
93.13
93.07
77.37
77.16
76.94
74.74
74.70
70.30
70.22
47.00
27.11
24.03
24.00
23.72
23.68
OPr-i
OPr-i
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

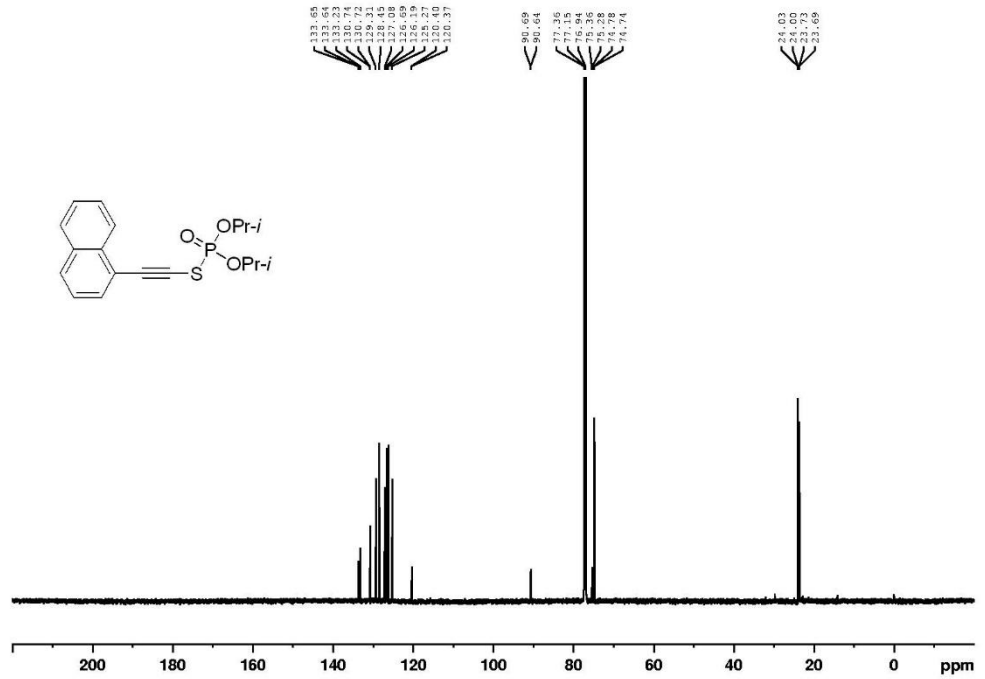
44


14.91
OPr-i
OPr-i
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

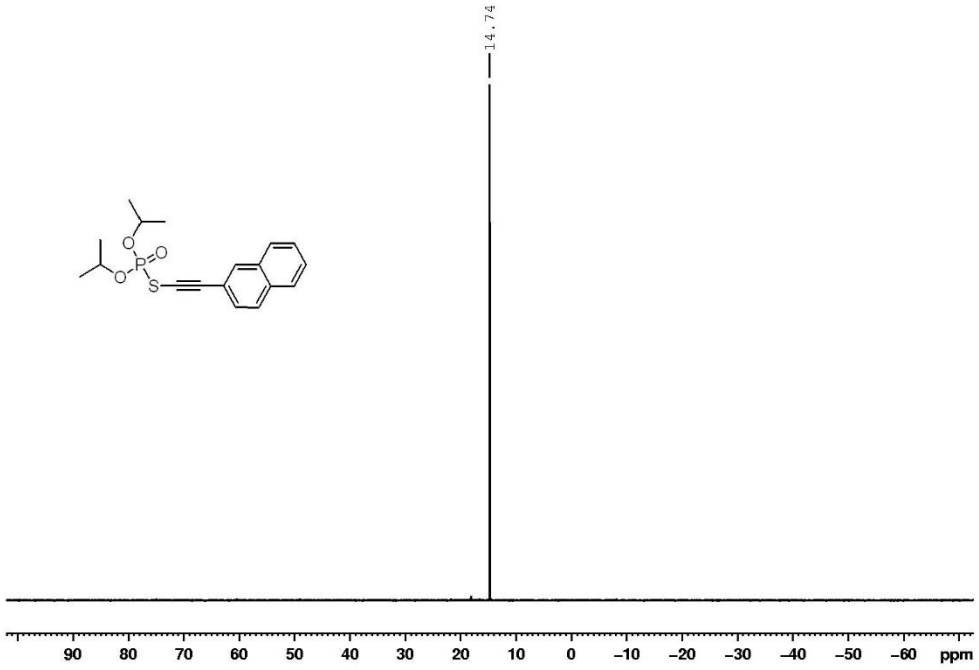
44


8.324
8.310
7.856
7.843
7.830
7.652
7.640
7.587
7.585
7.575
7.573
7.562
7.560
7.537
7.535
7.524
7.522
7.512
7.510
7.426
7.413
7.412
7.400
5.023
5.013
5.008
5.003
4.998
4.992
4.988
4.982
4.977
4.967
1.475
1.471
1.465
1.460
OPr-i
OPr-i
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
1.00
2.08
1.04
1.04
1.06
1.08
2.05
12.06

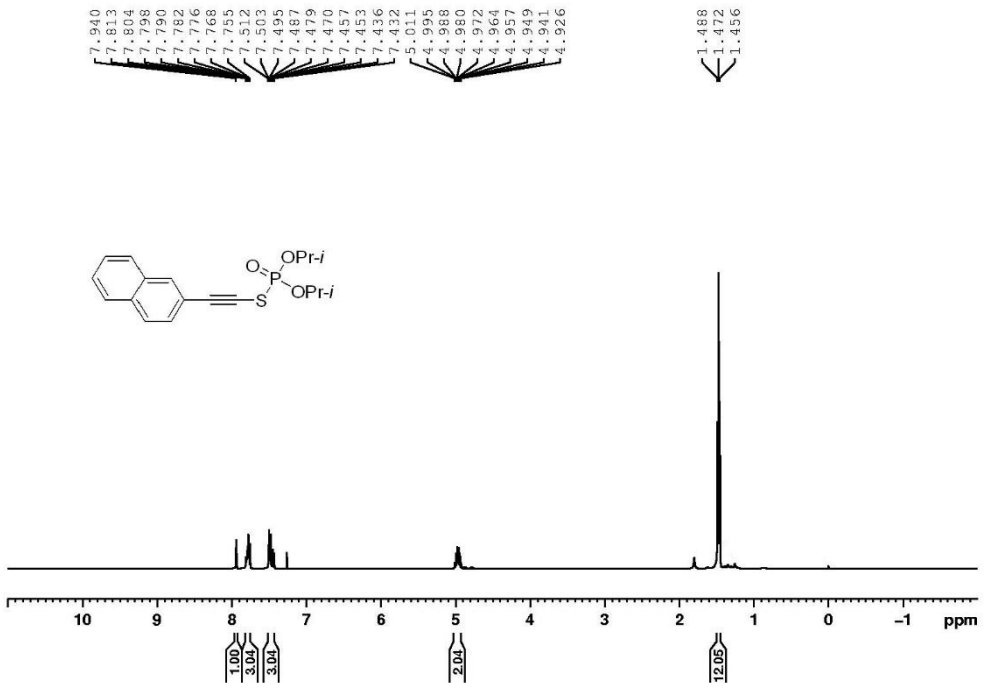
44


133.65
133.64
133.23
130.74
130.72
129.31
128.45
127.08
126.69
126.59
126.27
120.40
120.37
90.69
90.64
77.36
77.15
76.94
75.36
75.28
74.78
74.74
24.03
23.90
23.77
23.69
OPr-i
OPr-i
200
180
160
140
120
100
80
60
40
20
0
ppm

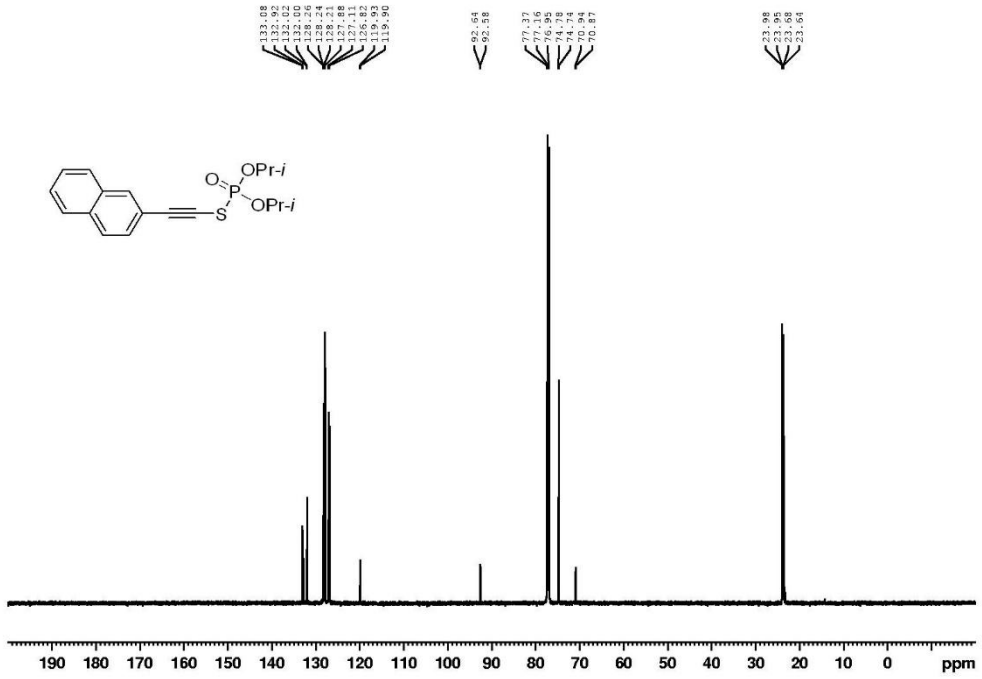
45


14.74
90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 ppm

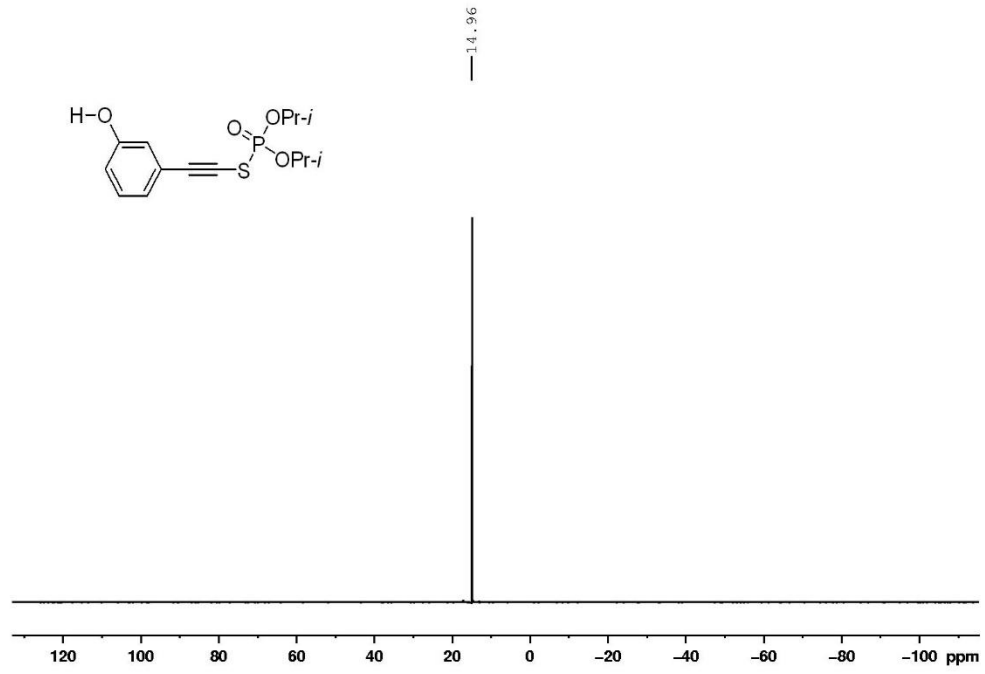
45


7.940
7.813
7.804
7.798
7.790
7.782
7.776
7.768
7.755
7.512
7.503
7.495
7.487
7.479
7.470
7.457
7.453
7.436
7.432
5.011
4.995
4.988
4.980
4.972
4.964
4.957
4.949
4.941
4.926
1.488
1.472
1.456
OPr-i
OPr-i
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
1.00
3.04
3.04
2.04
12.05

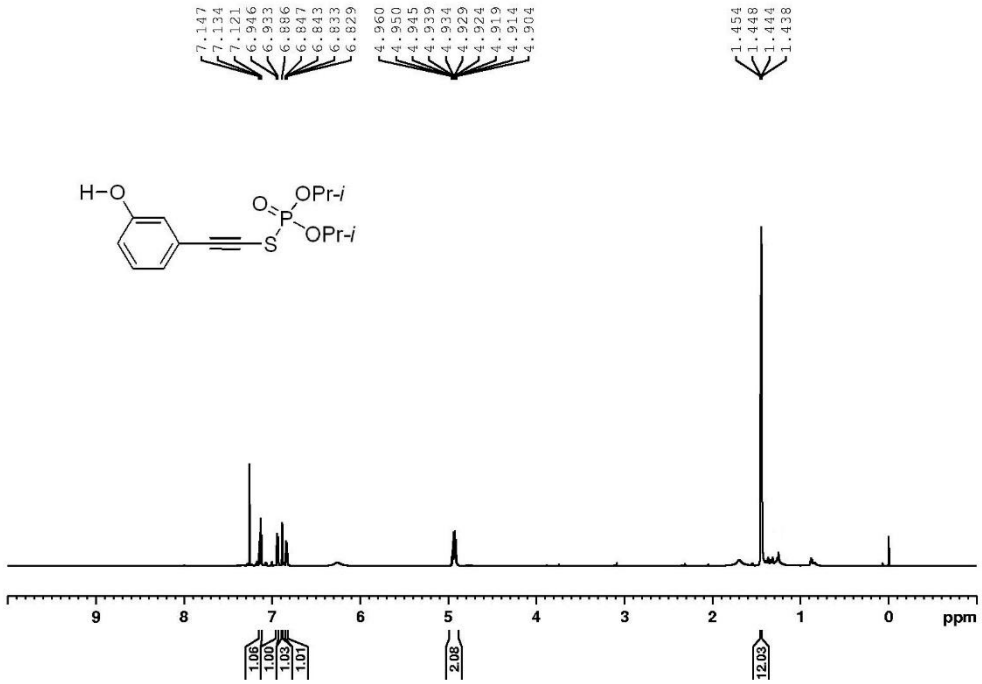
45


133.08
132.92
132.62
132.00
128.26
128.24
127.71
127.68
127.11
126.82
119.93
119.90
92.64
92.58
77.37
77.16
76.95
74.78
74.74
70.84
70.87
23.98
23.95
23.68
23.64
OPr-i
OPr-i
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

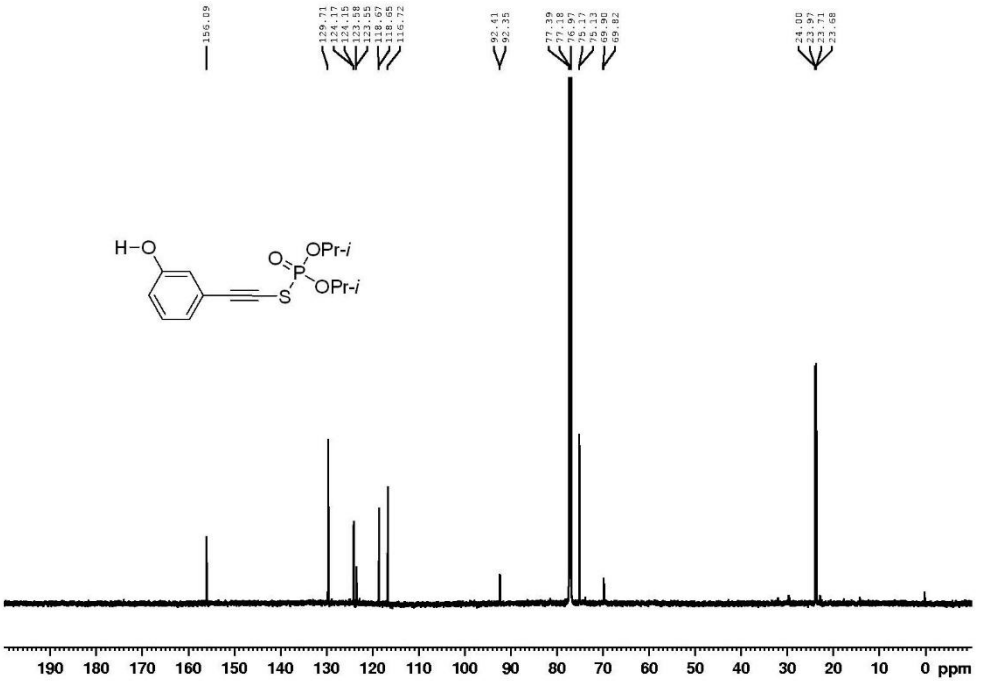
46


14.96
H–O
OPr-i
OPr-i
120 100 80 60 40 20 0 –20 –40 –60 –80 –100 ppm

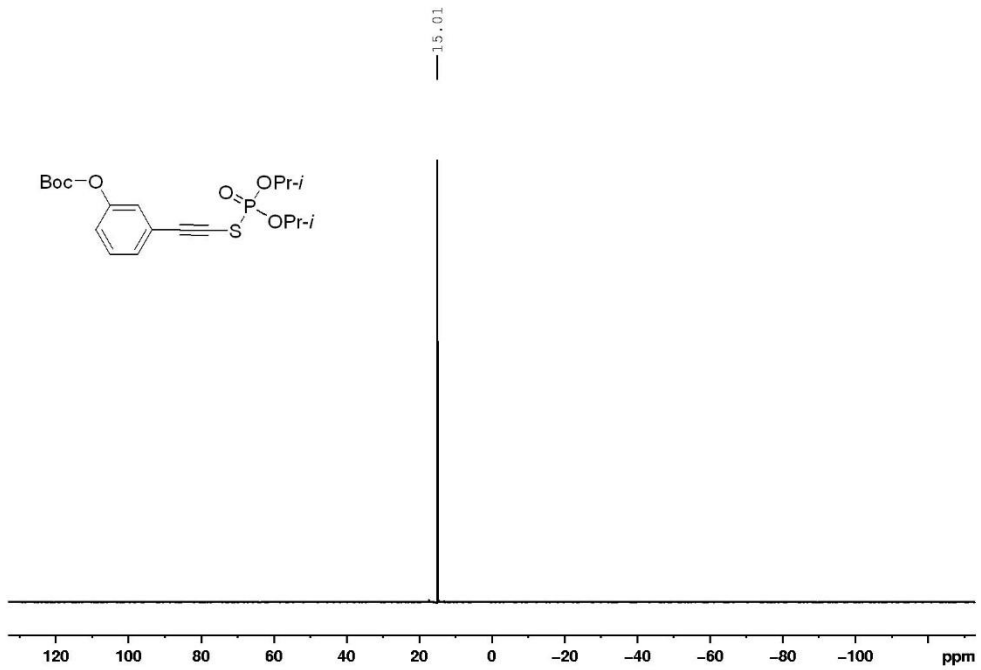
46


7.147
7.134
7.121
6.946
6.933
6.886
6.847
6.843
6.833
6.829
4.960
4.950
4.945
4.939
4.934
4.929
4.924
4.919
4.914
4.904
1.454
1.448
1.444
1.438
H–O
OPr-i
OPr-i
S
9
8
7
6
5
4
3
2
1
0
ppm
1.06
1.00
1.03
1.01
2.08
12.03

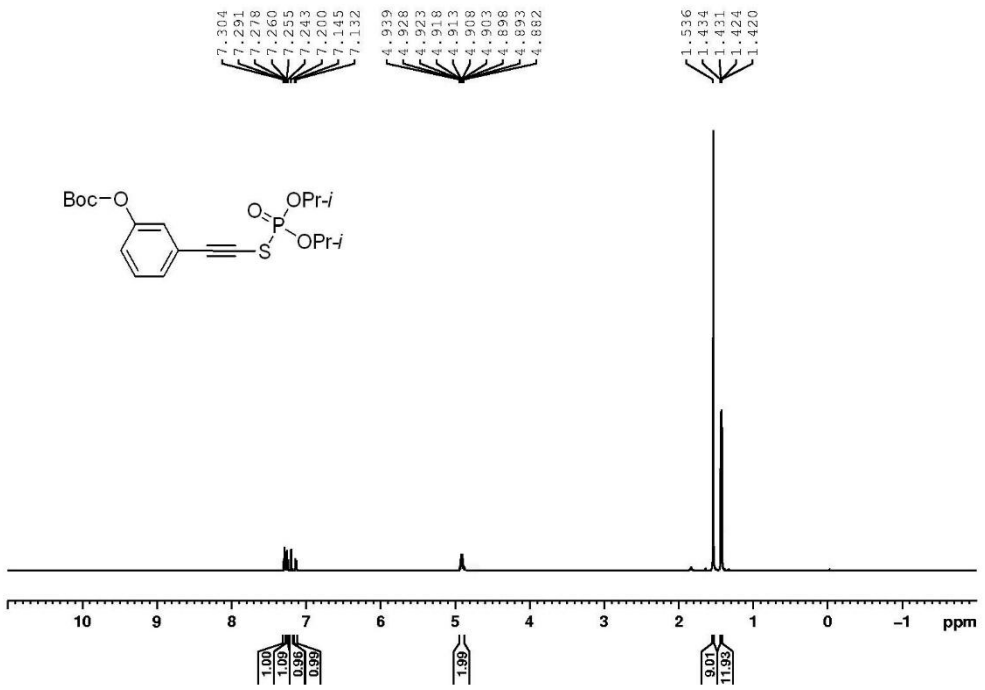
46


156.09
129.71
124.17
124.15
123.58
123.55
118.67
118.65
116.72
92.41
92.35
77.39
77.18
76.97
76.75
75.13
69.90
69.82
24.00
23.97
23.71
23.68
H–O
OPr-i
OPr-i
S
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0 ppm

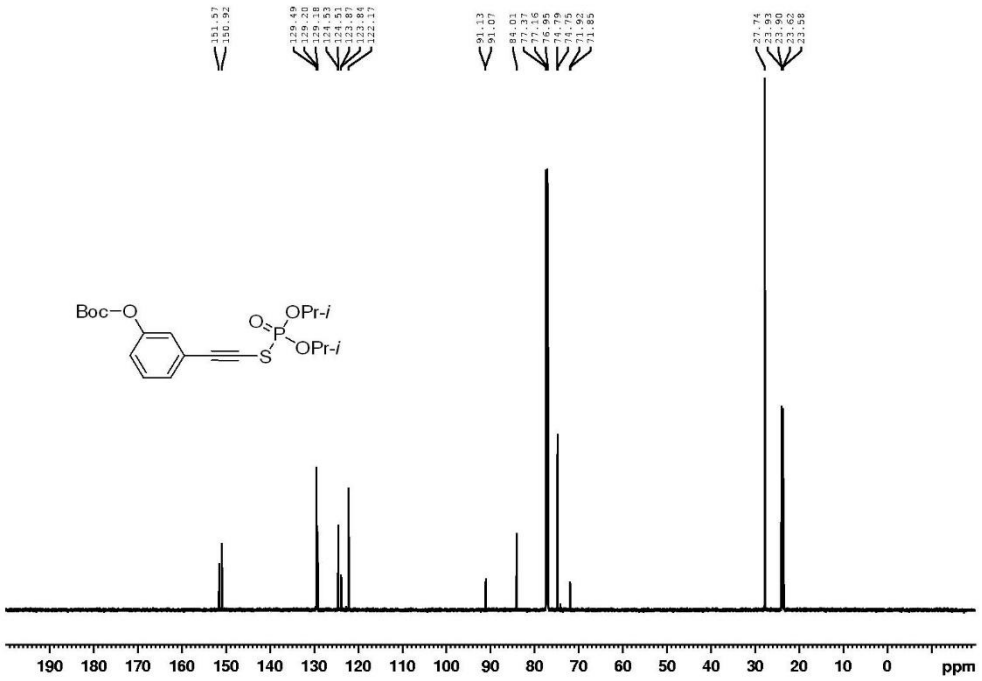
47


15.01
Boc–O
OPr-*i*
O
P
OPr-*i*
S
120
100
80
60
40
20
0
–20
–40
–60
–80
–100
ppm

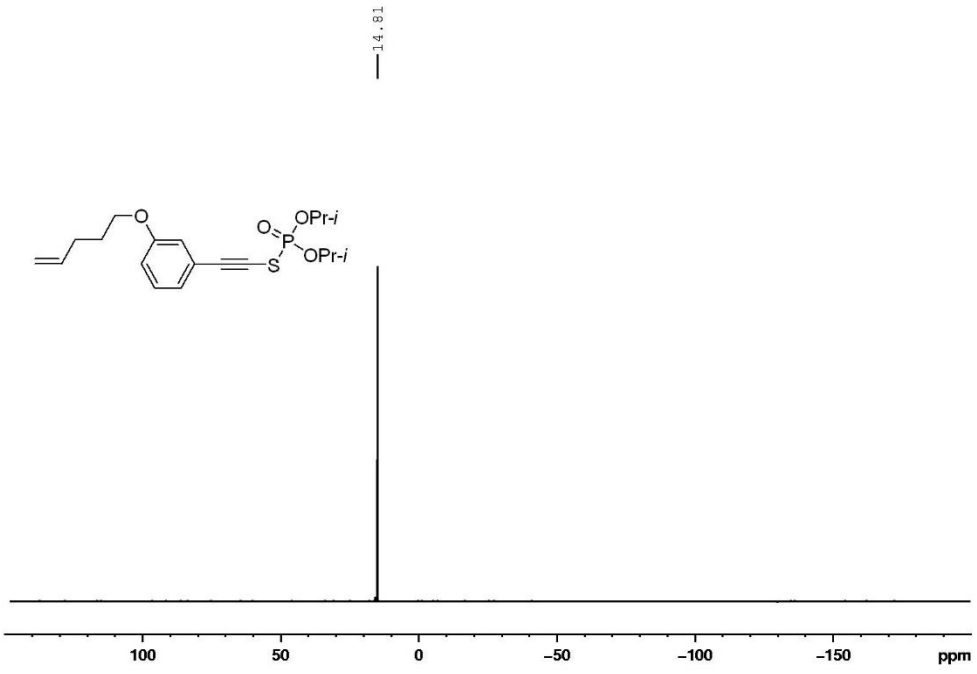
47


7.304
7.291
7.278
7.260
7.255
7.243
7.200
7.145
7.132
4.939
4.928
4.923
4.918
4.913
4.908
4.903
4.898
4.893
4.882
1.536
1.434
1.431
1.424
1.420
Boc–O
OPr-*i*
O
P
OPr-*i*
S
10
9
8
7
6
5
4
3
2
1
0
–1
ppm
1.00
1.09
0.96
0.99
1.99
9.01
11.93

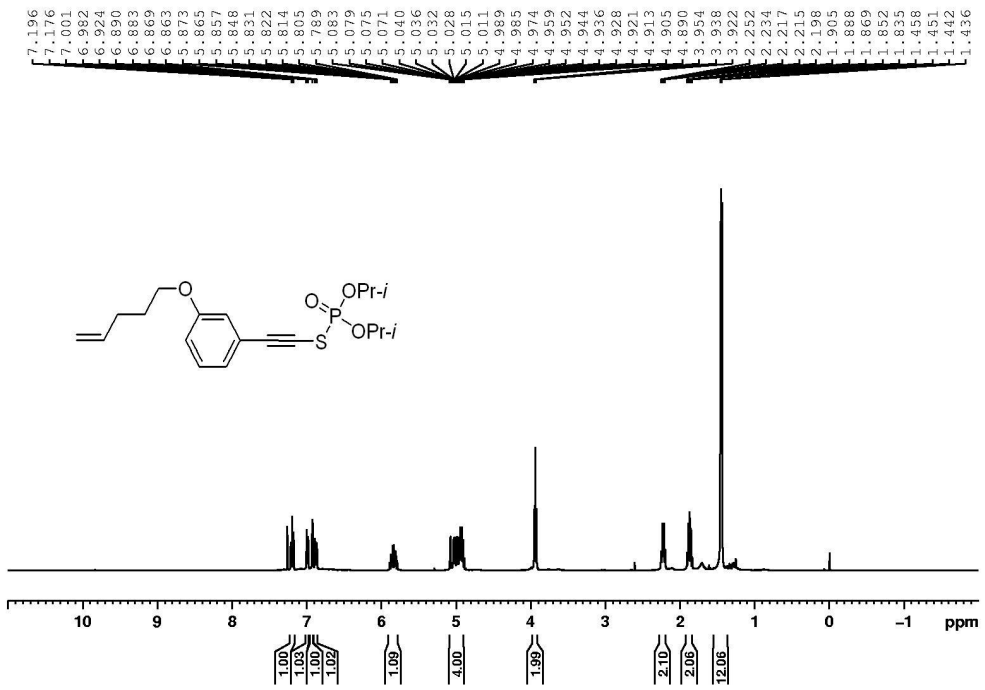
47


151.57
150.92
129.49
129.20
129.18
124.53
124.51
123.87
123.86
122.17
91.13
91.07
84.01
77.37
77.16
76.95
76.79
74.75
71.92
71.85
27.74
23.93
23.90
23.62
23.58
Boc–O
OPr-i
OPr-i
S
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

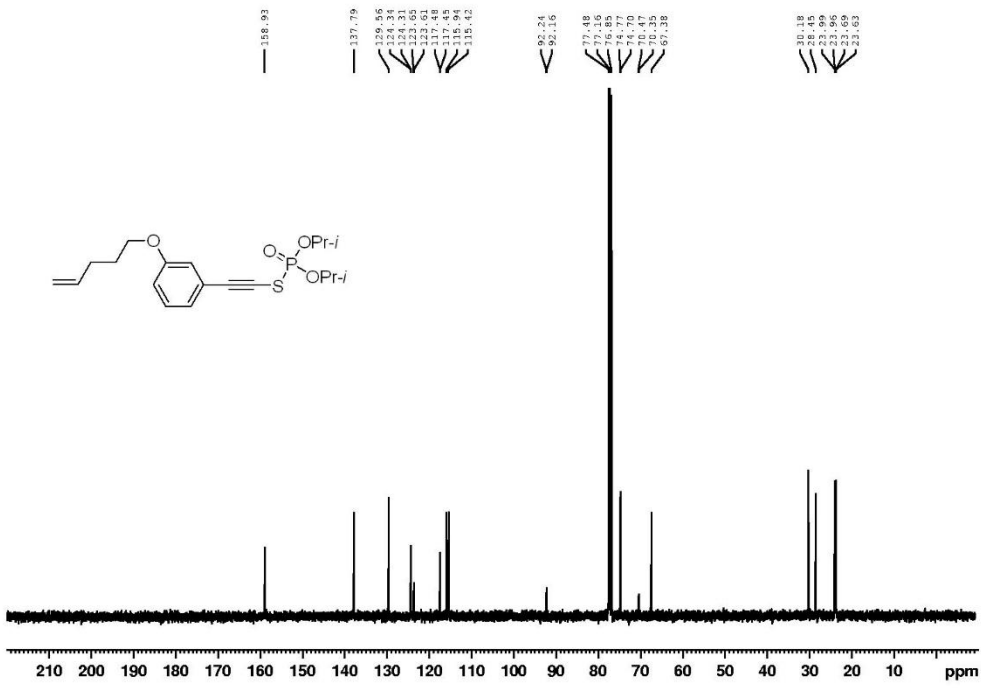
48


14.81
O
OPr-i
OPr-i
S
100 50 0 –50 –100 –150 ppm

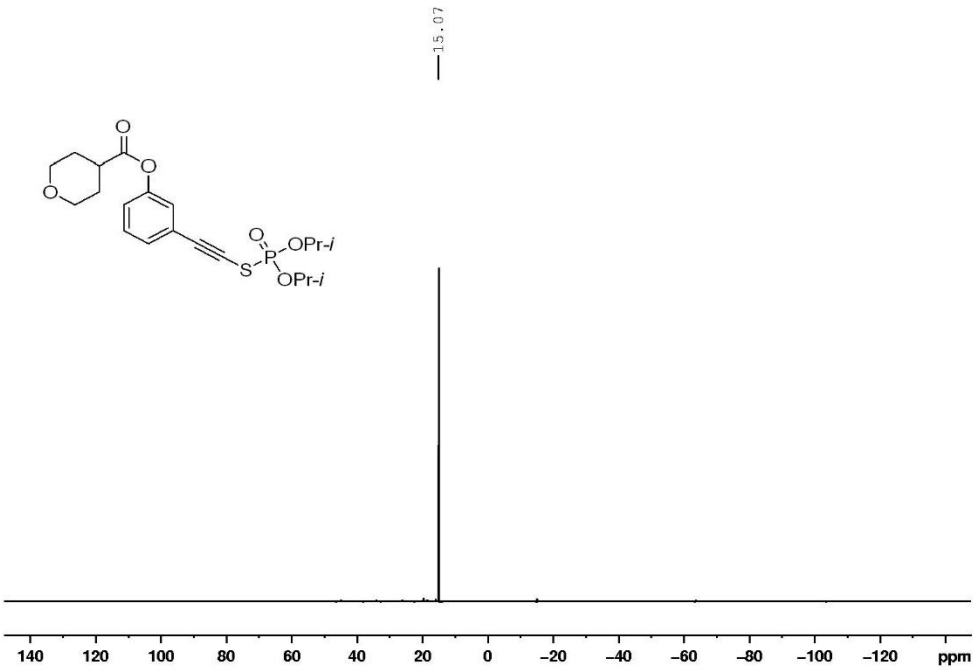
48


7.196
7.176
7.001
6.982
6.924
6.890
6.883
6.869
6.863
5.873
5.865
5.857
5.848
5.831
5.822
5.814
5.805
5.789
5.083
5.079
5.075
5.071
5.040
5.036
5.032
5.028
5.015
5.011
4.989
4.985
4.974
4.959
4.952
4.944
4.936
4.928
4.921
4.913
4.905
4.890
3.954
3.938
3.922
2.252
2.234
2.217
2.215
2.198
1.905
1.888
1.869
1.852
1.835
1.458
1.451
1.442
1.436
OPr-i
OPr-i
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
1.00
1.03
1.00
1.02
1.09
4.00
1.99
2.10
2.06
12.06

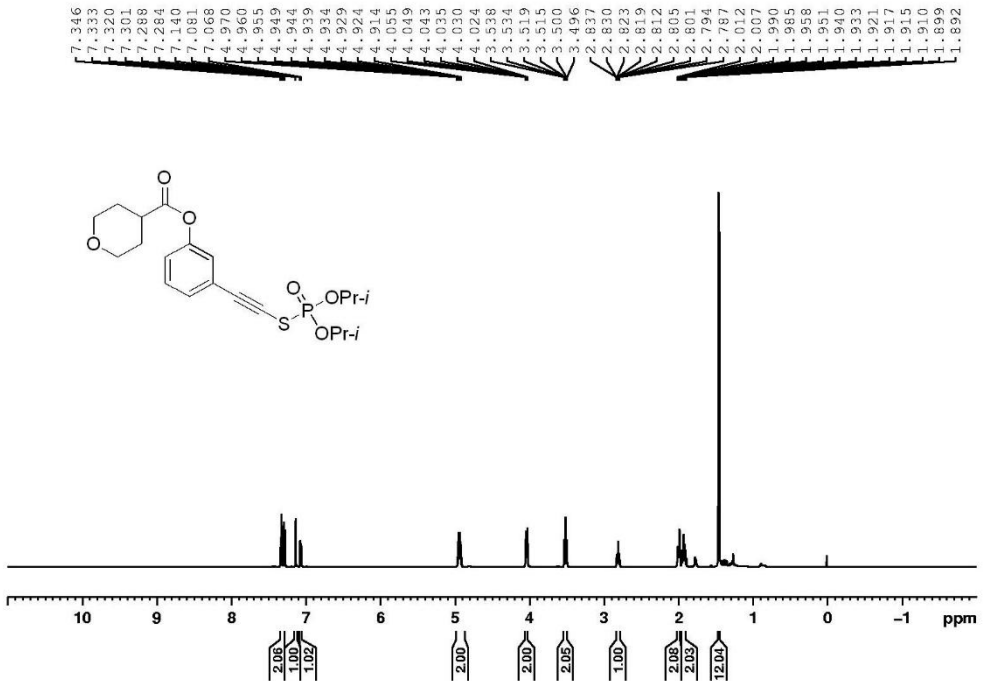
48


158.93
137.79
129.56
124.34
124.31
123.65
123.61
117.48
117.45
116.94
116.42
92.24
92.16
77.48
77.16
76.85
74.77
74.70
70.47
70.35
67.38
30.18
28.45
23.99
23.96
23.69
23.63
OPr-i
OPr-i
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

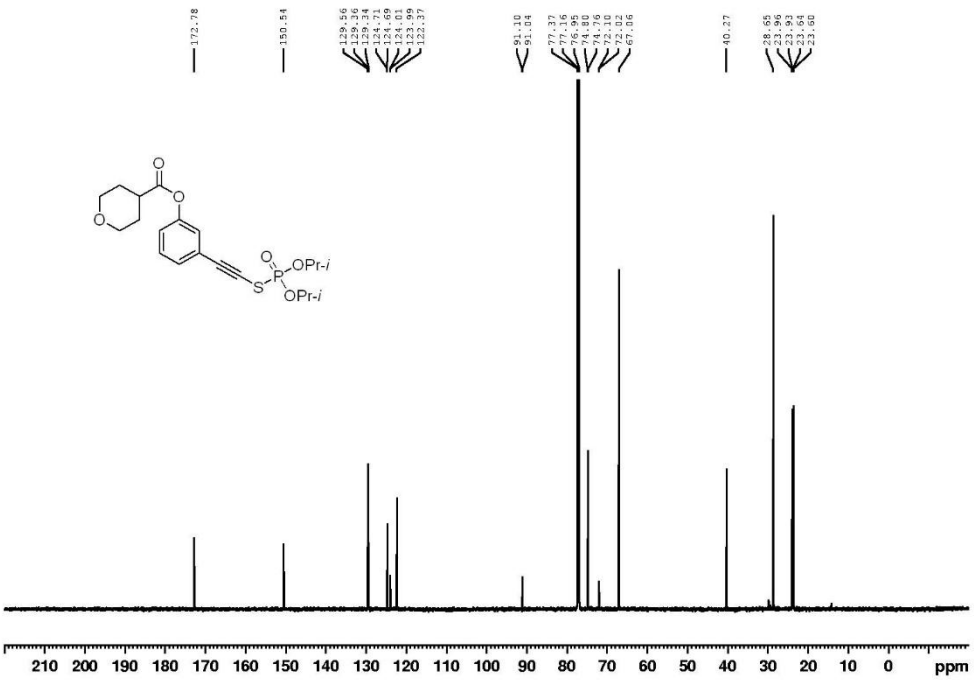
49


15.07
OPr-i
OPr-i
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 ppm

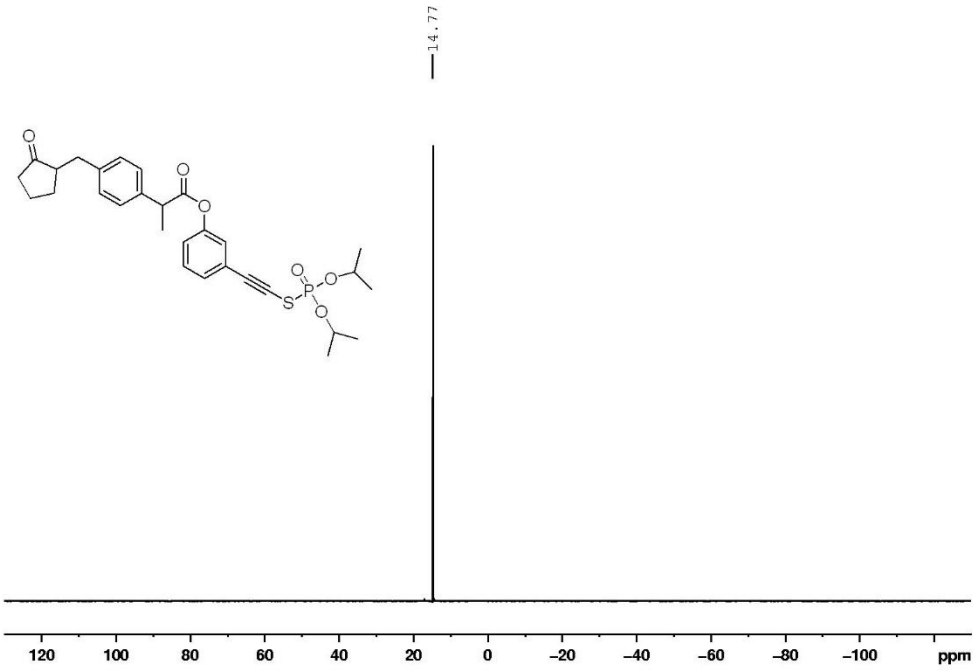
49


7.346 7.333 7.320 7.301 7.288 7.284 7.140 7.081 7.068 4.970 4.960 4.955 4.949 4.944 4.939 4.934 4.929 4.924 4.914 4.055 4.049 4.043 4.035 4.030 4.024 3.538 3.534 3.519 3.515 3.500 3.496 2.837 2.830 2.823 2.819 2.812 2.805 2.801 2.794 2.787 2.012 2.007 1.990 1.985 1.958 1.951 1.940 1.933 1.921 1.917 1.915 1.910 1.899 1.892
OPr-i
OPr-i
10 9 8 7 6 5 4 3 2 1 0 -1 ppm
2.08 1.00 1.02 2.00 2.00 2.05 1.00 2.08 2.03 12.04

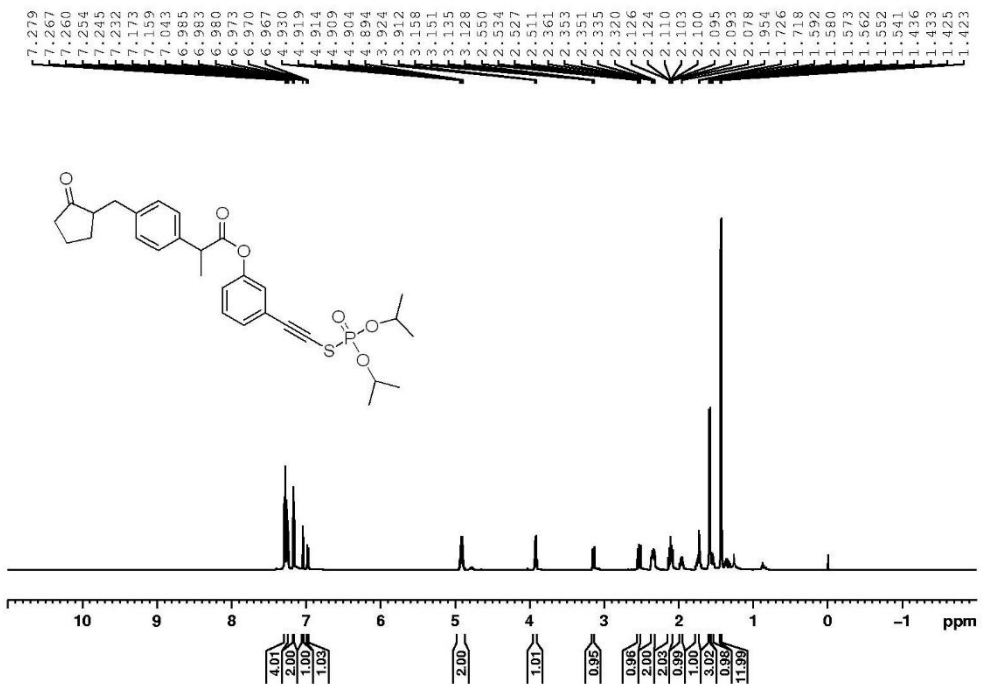
49


172.78
150.54
129.56
129.36
129.34
124.71
124.69
124.01
123.99
123.37
91.10
91.04
77.37
77.16
76.95
74.80
74.76
72.10
72.02
67.06
40.27
28.65
23.96
23.93
23.64
23.60
OPr-i
OPr-i
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

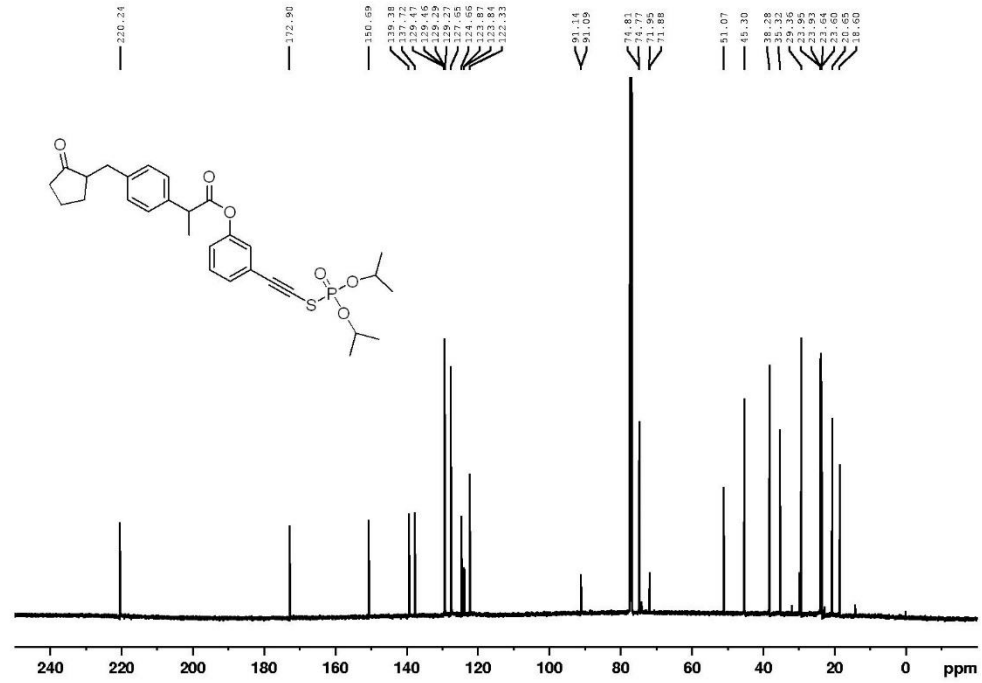
50


14.77
120 100 80 60 40 20 0 -20 -40 -60 -80 -100 ppm

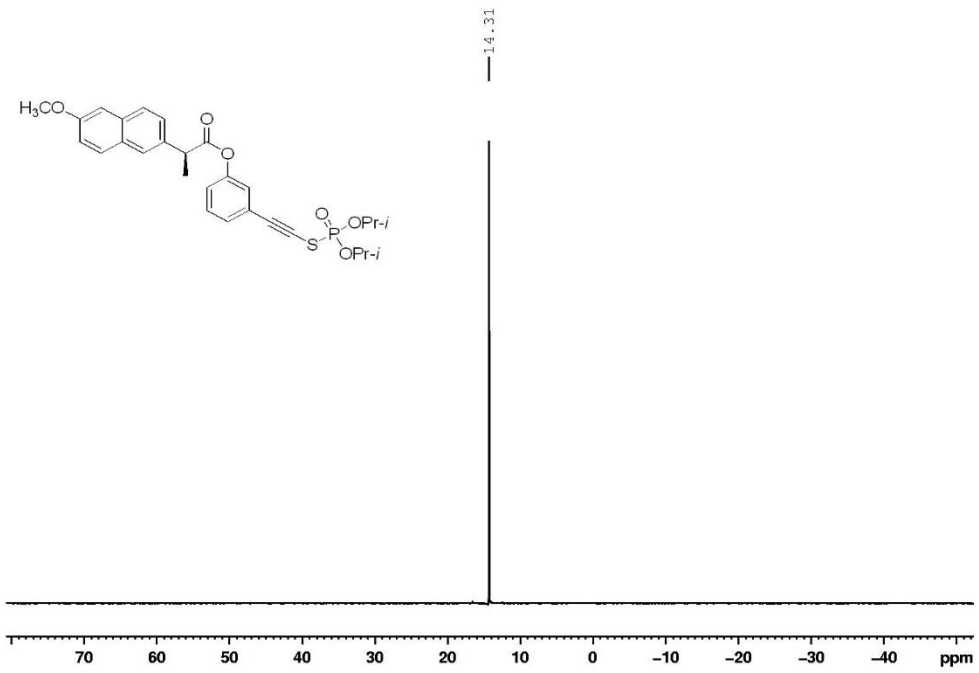
50


7.279
7.267
7.260
7.254
7.245
7.232
7.173
7.159
7.043
6.985
6.983
6.980
6.973
6.970
6.967
4.930
4.919
4.914
4.909
4.904
4.894
3.924
3.912
3.158
3.151
3.135
3.128
2.550
2.534
2.527
2.511
2.361
2.353
2.351
2.335
2.320
2.126
2.124
2.110
2.103
2.100
2.095
2.093
2.078
1.954
1.726
1.718
1.592
1.580
1.573
1.562
1.552
1.541
1.436
1.433
1.425
1.423
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
4.07 2.00 1.00 1.03 2.00 1.01 0.95 0.96 2.00 2.03 0.99 1.00 3.02 0.98 11.99

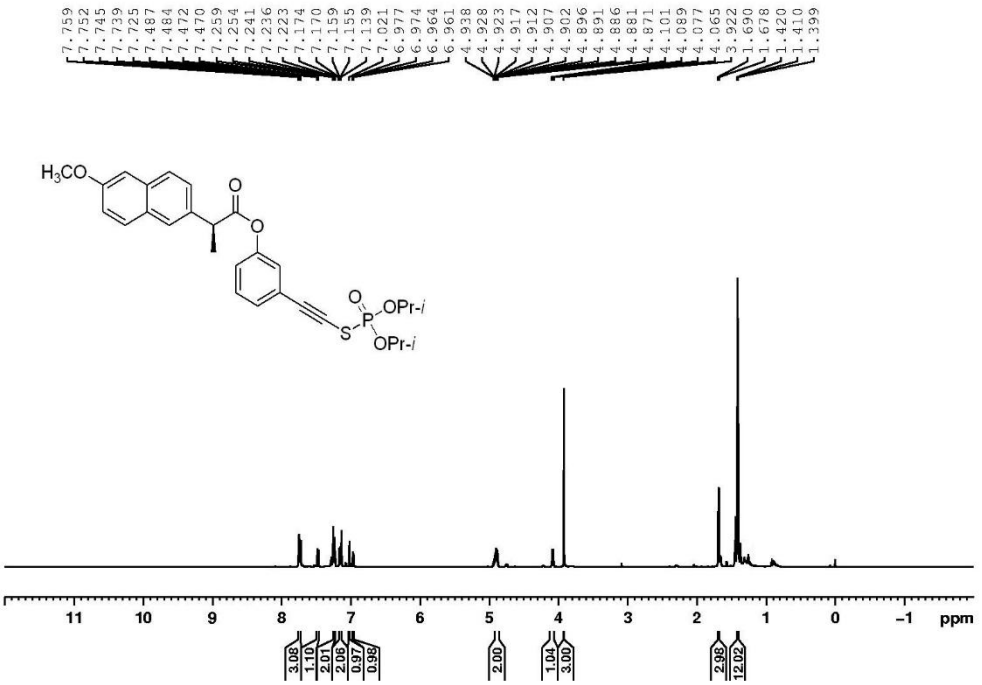
50


220.24
172.90
150.69
139.38
137.72
129.47
129.46
129.29
129.27
127.65
124.66
123.87
123.84
122.33
91.14
91.09
74.81
74.77
71.95
71.88
51.07
45.30
38.28
35.32
29.36
23.95
23.93
23.64
20.65
18.60
240 220 200 180 160 140 120 100 80 60 40 20 0 ppm

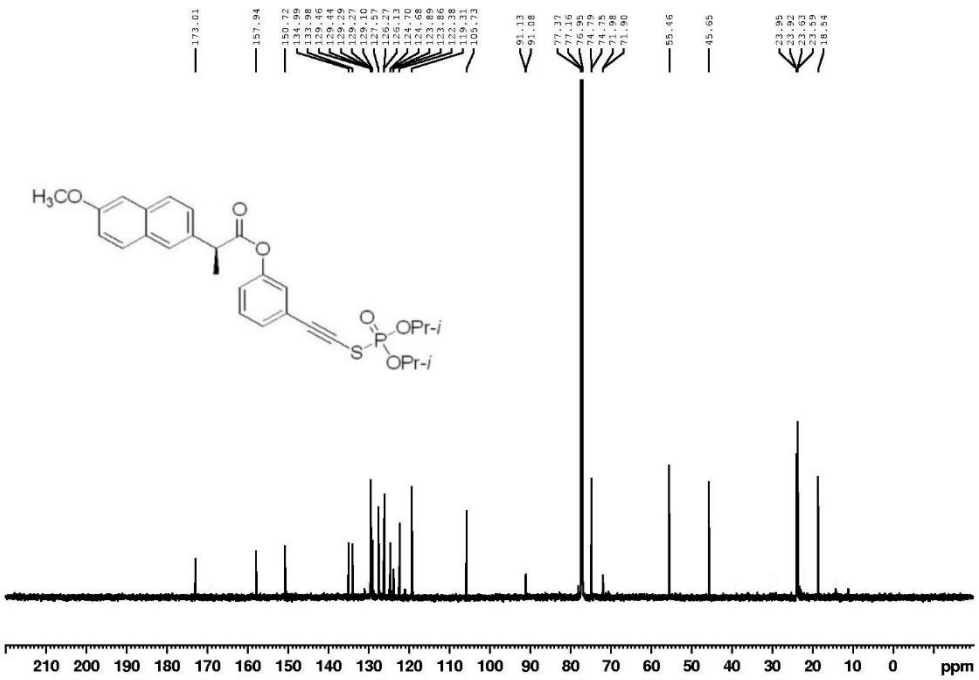
51


14.31
H3CO
OPr-i
OPr-i
70
60
50
40
30
20
10
0
-10
-20
-30
-40
ppm

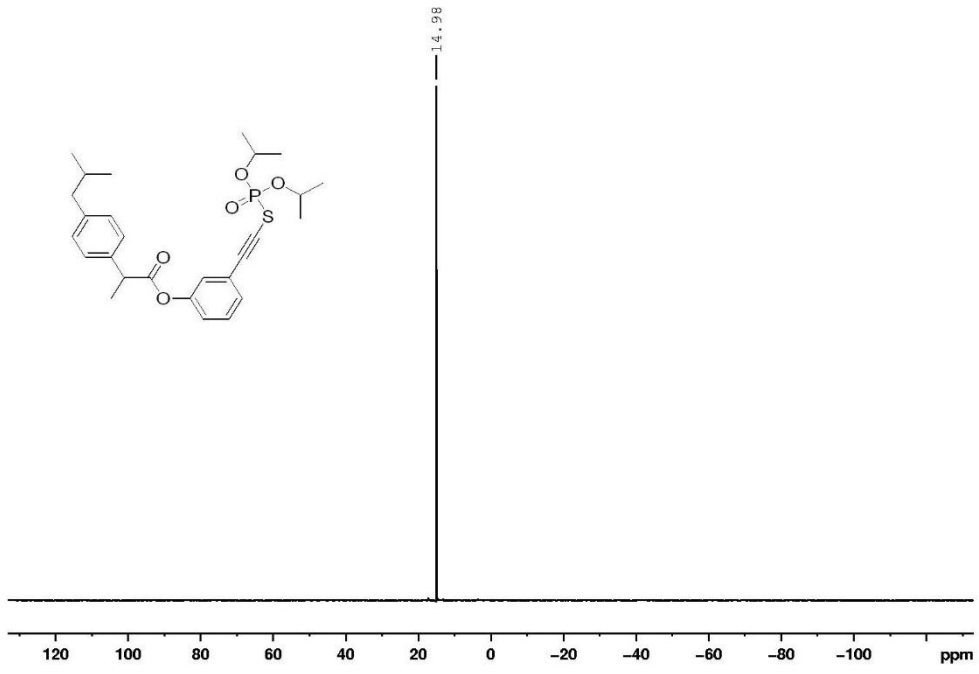
51


7.759
7.752
7.745
7.739
7.725
7.487
7.484
7.472
7.470
7.259
7.254
7.241
7.236
7.223
7.174
7.170
7.159
7.155
7.139
7.021
6.977
6.974
6.964
6.961
4.938
4.928
4.923
4.917
4.912
4.907
4.902
4.896
4.891
4.886
4.881
4.871
4.101
4.089
4.077
4.065
3.922
1.690
1.678
1.420
1.410
1.399
H3CO
OPr-i
OPr-i
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
3.08
1.10
2.01
2.09
0.97
0.98
2.00
1.04
3.00
2.98
12.02

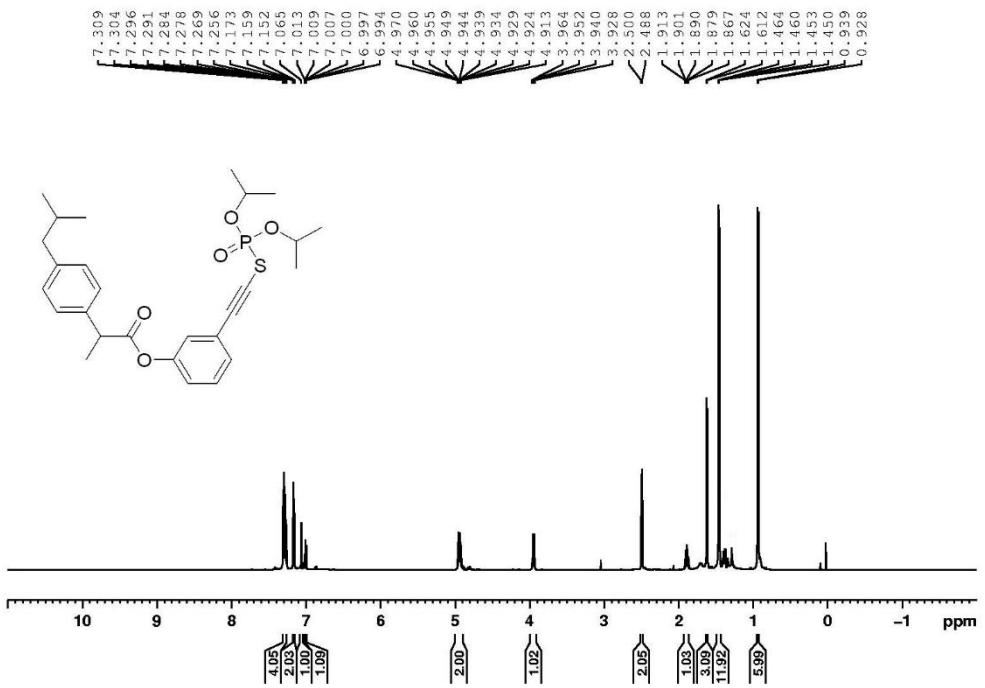
51


173.01
157.94
150.72
134.98
133.98
129.46
129.44
129.29
128.27
127.57
126.27
126.13
125.10
124.68
123.89
123.86
123.38
119.31
105.73
91.13
91.08
77.37
77.16
76.95
74.79
74.75
71.98
71.90
55.46
45.65
23.95
23.92
23.63
23.59
18.54
H3CO
O
O
O
S
P
OPr-i
OPr-i
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

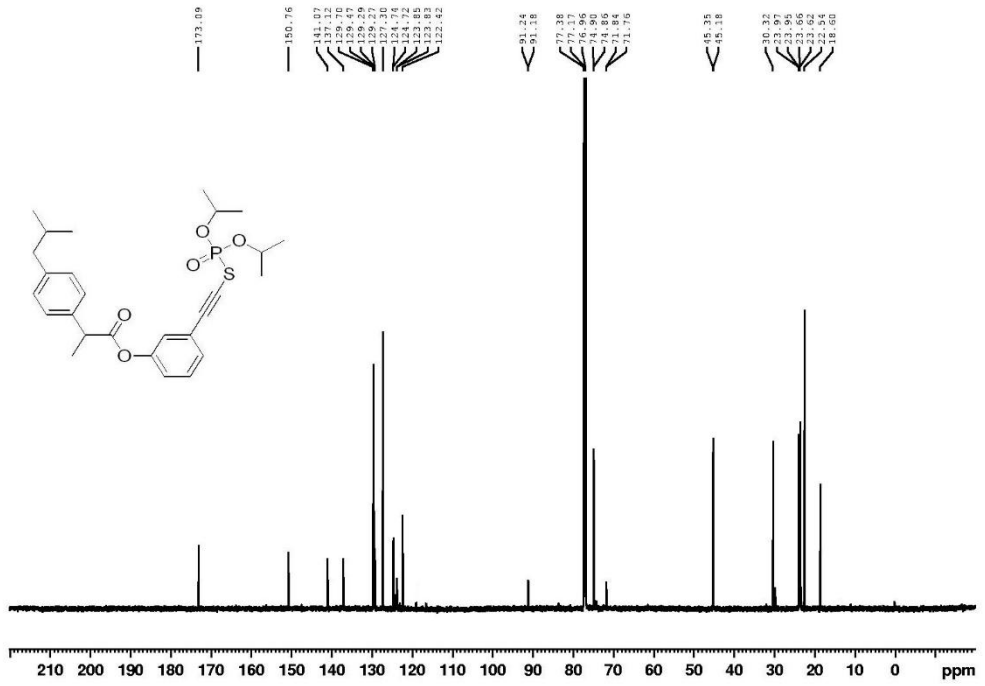
52


14.98
O
O
P
O
O
S
O
O
120 100 80 60 40 20 0 -20 -40 -60 -80 -100 ppm

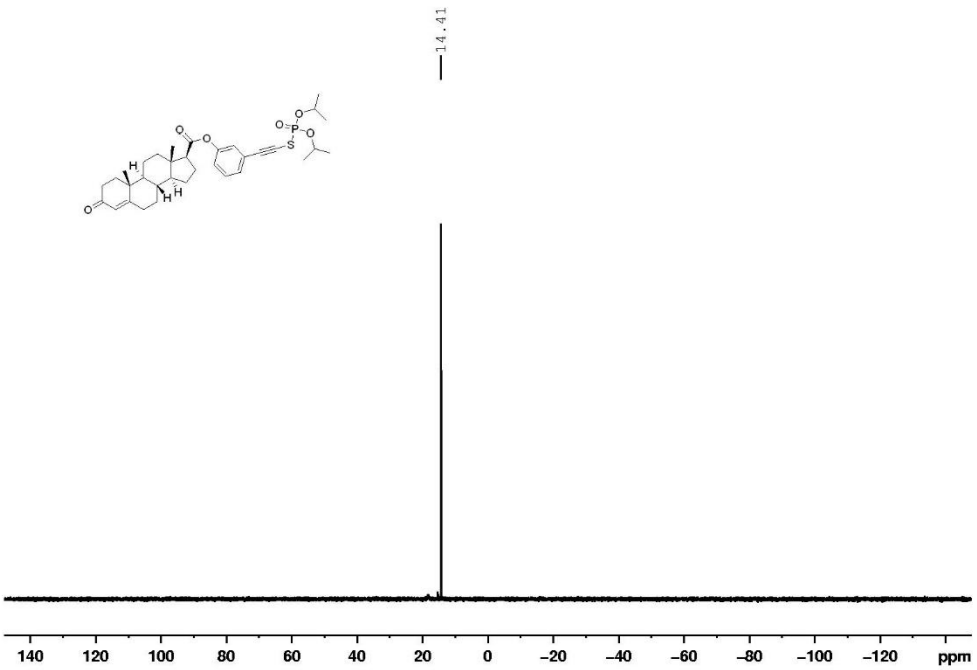
52


7.309
7.304
7.296
7.291
7.284
7.278
7.269
7.256
7.173
7.159
7.152
7.065
7.013
7.009
7.007
7.000
6.997
6.994
4.970
4.960
4.955
4.949
4.944
4.939
4.934
4.929
4.924
4.913
3.964
3.952
3.940
3.928
2.500
2.488
1.913
1.901
1.890
1.879
1.867
1.624
1.612
1.464
1.460
1.453
1.450
0.939
0.928
10 9 8 7 6 5 4 3 2 1 0 −1 ppm
4.05
2.03
1.00
1.09
2.00
1.02
2.05
1.03
3.00
11.92
5.99

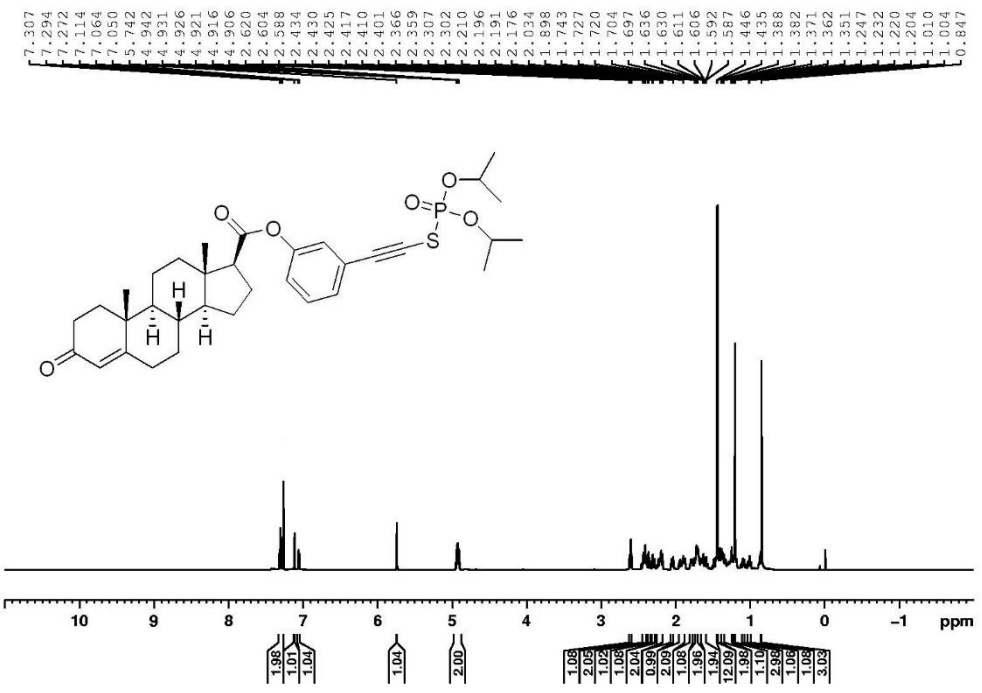
52


173.09
150.76
141.07
137.12
129.70
129.47
129.29
128.37
127.30
124.74
124.72
123.85
123.83
122.42
91.24
91.18
77.38
77.17
76.96
74.96
74.86
71.84
71.76
45.35
45.18
30.32
30.07
23.95
23.66
23.62
22.54
18.60
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

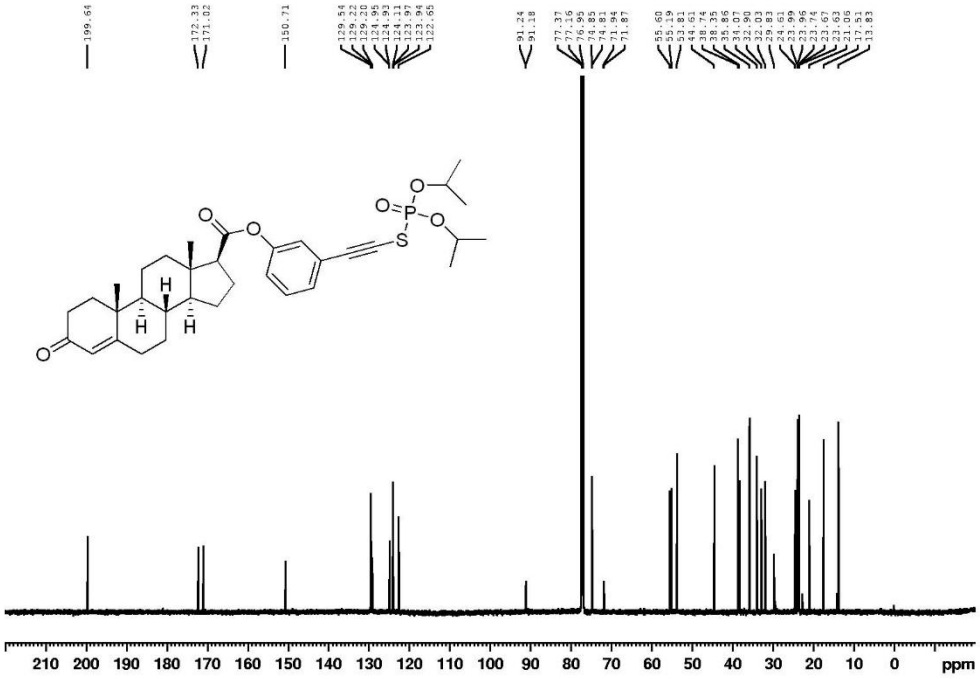
53


14.41
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
ppm

53


7.307
7.294
7.272
7.114
7.064
7.050
5.742
4.942
4.931
4.926
4.921
4.906
4.906
2.620
2.604
2.588
2.434
2.430
2.425
2.417
2.410
2.401
2.366
2.359
2.307
2.302
2.210
2.196
2.191
2.176
2.034
1.898
1.743
1.727
1.720
1.704
1.697
1.636
1.630
1.611
1.606
1.592
1.587
1.446
1.435
1.388
1.382
1.371
1.362
1.351
1.247
1.232
1.220
1.204
1.010
1.004
0.847
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
1.98
1.01
1.04
1.04
2.00
1.09
2.05
1.02
1.08
2.04
0.99
2.09
1.08
1.96
1.94
12.09
1.98
1.10
2.89
1.06
1.08
3.03

53


199.64
172.33
171.02
150.71
129.54
129.22
129.10
124.95
124.93
124.11
123.97
123.94
122.65
91.24
91.18
77.37
77.16
76.95
74.85
74.81
71.94
71.87
55.60
55.19
53.81
44.61
38.74
38.35
35.86
34.07
32.90
31.03
28.83
24.61
23.99
23.96
23.74
23.67
23.63
21.06
17.51
13.83
O
O
O
O
P
S
O
H
H
H
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm