Solvent-free Zn(OTf)2-catalyzed dehydrative cross coupling of propargyl alcohols with diarylphosphine oxides to afford allenylphosphine oxides

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**Supplemental Materials**

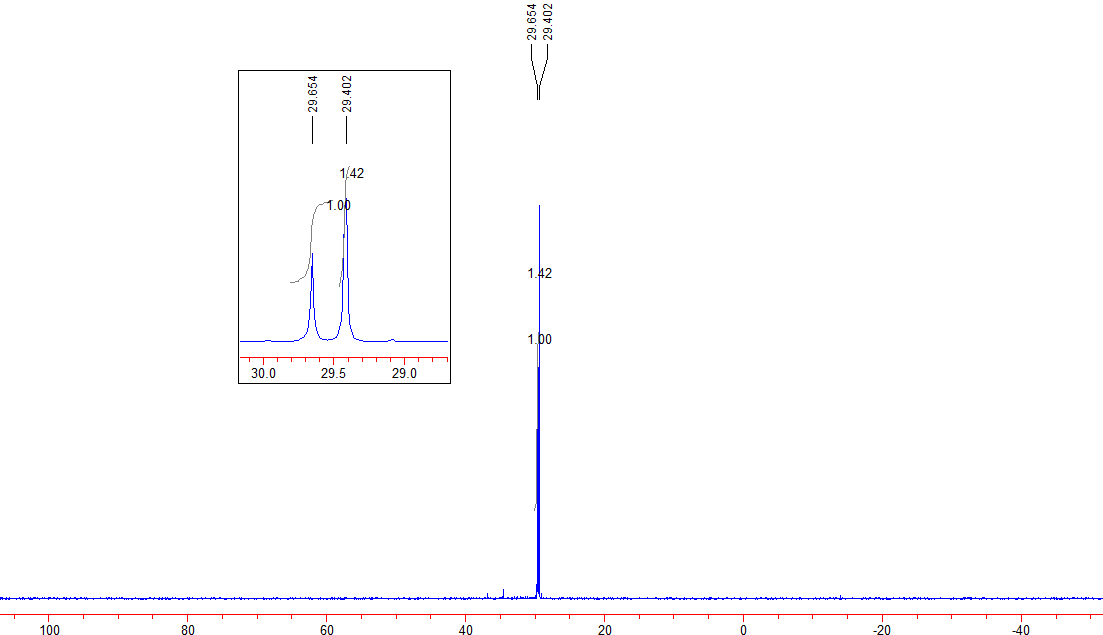
***General Information***. All reactions were performed under dry N2 atmosphere. Anhydrous solvents were distilled prior to use: THF was distilled from sodium using benzophenone as the indicator; MeCN, DCM and DMF were distilled from CaH2. Propargyl alcohols **1** were prepared following known method.1Diarylphosphine oxides **2** were purchased from commercial sources or prepared following known method.2 Flash chromatography was performed on silica gel using petroleum ether and EtOAc as eluent. 1H (400 MHz), 13C (100 MHz) and 31P NMR (162 MHz) spectra were recorded on a Bruke Ascend(TM) 400 MHz NMR spectrometer in CDCl3. Chemical shifts (ppm) were recorded with tetramethylsilane (TMS) as the internal reference standard. Chemical shifts are expressed in ppm and *J* values are given in Hz. HRMS analysis of the products (ESI-TOF) was performed at the Analytical Center of State Key Laboratory of Materials-Oriented Chemical Engineering at Nanjing Tech University, China.

**Competition experiment**

Reaction of **1a**, **1g** and **2a**



An oven-dried Schlenk tube containing a Teflon-coated stir bar was charged with Zn(OTf)2 (7.3 mg, 10 mol %), **1a** (38.1 mg, 0.2 mmol), **1g** (38.0 mg, 0.2 mmol) and **2a** (40.8 mg, 0.2 mmol). The Schlenk tube was sealed and then evacuated and backfilled with N2 (3 cycles). The Schlenk tube was sealed and immersed in an oil bath which was heated to 100 oC for 12 h. The reaction mixture was disolved in DCM, transfered into a round-bottom flask and concentrated under reduced pressure. The catalyst was removed by passing the reside through a very short silica chromatography to afford a mixture of the products. The mixture was dissolved in CDCl3 and the 31P NMR spectra was recorded (**Figure S<1>**). Based on the 31P NMR spectra, the ratio of **3a** (δ 29.40 ppm) to **3g** (δ 29.65 ppm) and the combined yields were calculated: **3a**/**3g** = 1.42/1, total NMR yield: >98%.

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**Figure S 1: 31P NMR of the crude reaction mixture**

**General procedure for the Zn(OTf)2-catalyzed dehydrative reaction of propargyl alcohols with diarylphosphine oxide**

An oven-dried Schlenk tube containing a Teflon-coated stir bar was charged with Zn(OTf)2 (0.1 equiv), propagylic alcohol **1** (2.0 equiv) and diarylphosphine oxide (1.0 equiv). The Schlenk tube was sealed and then evacuated and backfilled with N2 (3 cycles). The Schlenk tube was sealed and immersed in an oil bath which was heated to 100 oC. After the reaction was heated for 12 h, the mixture was dissolved in DCM and transferred into a round-bottom flask. Removal of the solvent under vacuum left a slurry residue, which was purified by flash chromatography on silica (petroleum ether/ethyl acetate 3/1 to 1/1) to afford the product **3**.

**Characterization data of the products 3**



**(4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)diphenylphosphine oxide (3a):** 69.2 mg (yield 93%), prepared from 75.4 mg of **1a** (0.4 mmol) and 40.4 mg of **2a** (0.2 mmol). Known compound.3 1H NMR (CDCl3, 400 MHz): *δ* =7.78–7.73 (m, 2H), 7.66–7.60 (m, 2H), 7.52–7.48 (m, 1H), 7.45–7.40 (m, 2H), 7.30–7.15 (m, 6H), 7.00 (d, *J* = 8.0 Hz, 2H), 6.02 (d, *J* = 11.2 Hz, 1H), 1.34 (s, 9H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.2.



**(1-(4-chlorophenyl)-4,4-dimethylpenta-1,2-dien-3-yl)diphenylphosphine oxide (3b):** 76.8 mg (yield 95%), prepared from 89.1 mg of **1b** (0.4 mmol) and 40.7 mg of **2a** (0.2 mmol). Known compound.3 1H NMR (CDCl3, 400 MHz): *δ* =7.79–7.74 (m, 2H), 7.63–7.58 (m, 2H), 7.52–7.42 (m, 3H), 7.31–7.29 (m, 1H), 7.23–7.17 (m, 4H), 6.90 (d, *J* = 8.0 Hz, 2H), 5.98 (d, *J* = 11.2 Hz, 1H), 1.33 (s, 9H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.0.



**(1-(4-fluorophenyl)-4,4-dimethylpenta-1,2-dien-3-yl)diphenylphosphine oxide (3c):** 73.3 mg (yield 94%), prepared from 83.2 mg of **1c** (0.4 mmol) and 40.5 mg of **2a** (0.2 mmol). Known compound.3 1H NMR (CDCl3, 400 MHz): *δ* =7.80–7.75 (m, 2H), 7.62–7.57 (m, 2H), 7.54–7.42 (m, 3H), 7.30–7.26 (m, 1H), 7.22–7.18 (m, 2H), 6.95–6.88 (m, 4H), 6.00 (d, *J* = 11.2 Hz, 1H), 1.33 (s, 9H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.3.



**(1-(4-bromophenyl)-4,4-dimethylpenta-1,2-dien-3-yl)diphenylphosphine oxide (3d):** 85.7 mg (yield 95%), prepared from 107.2 mg of **1d** (0.4 mmol) and 40.4 mg of **2a** (0.2 mmol). This is a known compound.3 1H NMR (CDCl3, 400 MHz): *δ* =7.79–7.74 (m, 2H), 7.63–7.58 (m, 2H), 7.54–7.42 (m, 3H), 7.34–7.29 (m, 3H), 7.25–7.20 (m, 2H), 6.84 (d, *J* = 7.6 Hz, 2H), 5.96 (d, *J* = 11.2 Hz, 1H), 1.32 (s, 9H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.2.



**(1-(2-chlorophenyl)-4,4-dimethylpenta-1,2-dien-3-yl)diphenylphosphine oxide (3e):** 66.0 mg (yield 81%), prepared from 89.5 mg of **1f** (0.4 mmol) and 40.6 mg of **2a** (0.2 mmol). This is a known compound.31H NMR (CDCl3, 400 MHz): *δ* =7.82–7.77 (m, 2H), 7.60–7.52 (m, 3H), 7.49–7.45 (m, 2H), 7.29–7.16 (m, 4H), 7.14–7.06 (m, 3H), 6.46 (d, *J* = 11.2 Hz, 1H), 1.34 (s, 9H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.1.



**diphenyl(1-phenylhepta-1,2-dien-3-yl)phosphine oxide (3g):** 54.9 mg (yield 74%), prepared from 75.5 mg of **1g** (0.4 mmol) and 40.4 mg of **2a** (0.2 mmol). This is a known compound.31H NMR (CDCl3, 400 MHz): *δ* =7.78–7.69 (m, 4H), 7.52–7.48 (m, 1H), 7.43–7.31 (m, 5H), 7.28–7.24 (m, 2H), 7.21–7.17 (m, 1H), 7.09-7.07 (m, 2H), 6.11 (dt, *J1* = 11.2 Hz, *J2* = 3.2 Hz, 1H), 2.50–2.30 (m, 2H), 1.60–1.51 (m, 2H), 1.37–1.31 (m, 2H), 0.84 (t, *J* = 7.2 Hz, 3H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.5.



**(1-(4-fluorophenyl)hepta-1,2-dien-3-yl)diphenylphosphine oxide (3h):** 55.9 mg (yield 72%), prepared from 83.2 mg of **1h** (0.4 mmol) and 40.4 mg of **2a** (0.2 mmol). This is a known compound.31H NMR (CDCl3, 400 MHz): *δ* =7.79–7.74 (m, 2H), 7.71–7.66 (m, 2H), 7.54–7.50 (m, 1H), 7.46–7.39 (m, 3H), 7.35–7.30 (m, 2H), 7.05–7.02 (m, 2H), 6.97–6.92 (m, 2H), 6.09 (dt, *J1* = 10.8 Hz, *J2* = 3.2 Hz, 1H), 2.50–2.29 (m, 2H), 1.59–1.50 (m, 2H), 1.37–1.31 (m, 2H), 0.84 (t, *J*= 7.4 Hz, 3H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.6.



**diphenyl(1-(4-(trifluoromethyl)phenyl)hepta-1,2-dien-3-yl)phosphine oxide (3i):** 41.5 mg (yield 47%), prepared from 102.8 mg of **1i** (0.4 mmol) and 40.5 mg of **2a** (0.2 mmol). This is a known compound.3 1H NMR (CDCl3, 400 MHz): *δ* =7.79–7.66 (m, 4H), 7.53–7.40 (m, 6H), 7.36-7.32 (m, 2H), 7.16 (d, *J*= 8.0 Hz, 2H), 6.13 (dt, *J1* = 9.2 Hz, *J2* = 3.2 Hz, 1H), 2.52–2.31 (m, 2H), 1.59–1.50 (m, 2H), 1.37–1.32 (m, 2H), 0.84 (t, *J*= 7.6 Hz, 3H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.6.



**(4,4-dimethyl-1,1-diphenylpenta-1,2-dien-3-yl)diphenylphosphine oxide (3k):** 85.2 mg (yield 95%), prepared from 105.6 mg of **1k** (0.4 mmol) and 40.5 mg of **2a** (0.2 mmol). This is a known compound.31H NMR (CDCl3, 400 MHz): *δ* =7.61–7.56 (m, 4H), 7.40–7.36 (m, 2H), 7.28–7.26 (m, 10H), 6.97–6.94 (m, 4H), 1.35 (s, 9H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.0.



**(1,1-diphenylhepta-1,2-dien-3-yl)diphenylphosphine oxide (3l):** 59.8 mg (yield 67%), prepared from 105.5 mg of **1l** (0.4 mmol) and 40.2 mg of **2a** (0.2 mmol). This is a known compound.31H NMR (CDCl3, 400 MHz): *δ* =7.66–7.61 (m, 4H), 7.46–7.42 (m, 2H), 7.34–7.26 (m, 10H), 6.99–6.97 (m, 4H), 2.47–2.41 (m, 2H), 1.67–1.59 (m, 2H), 1.35–1.31 (m, 2H), 0.83 (t, *J* = 7.4 Hz, 3H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.9.



**cyclohexylidene-3,3-dimethylbut-1-en-2-yl)diphenylphosphine oxide (3m):** 19.1 mg (yield 26%), prepared from 72.2 mg of **1m** (0.4 mmol) and 40.4 mg of **2a** (0.2 mmol). This is a known compound.3 1H NMR (CDCl3, 400 MHz): *δ* =7.71–7.66 (m, 4H), 7.49–7.40 (m, 6H), 2.00–1.93 (m, 2H), 1.77–1.70 (m, 2H), 1.44–1.37 (m, 2H), 1.34–1.26 (m, 2H), 1.21 (s, 9H), 1.10–1.02 (m, 2H). 31P NMR (CDCl3, 162 MHz): *δ* = 31.6.



**(1,3-diphenylpropa-1,2-dien-1-yl)diphenylphosphine oxide (3n):** 15.7 mg (yield 20%), prepared from 83.7 mg of **1n** (0.4 mmol) and 40.6 mg of **2a** (0.2 mmol). This is a known compound.31H NMR (CDCl3, 400 MHz): *δ* =7.80–7.72 (m, 4H), 7.68 (d, *J* = 8.0 Hz, 2H), 7.48–7.44 (m, 1H), 7.39–7.21 (m, 11H), 7.12 (d, *J* = 7.6 Hz, 2H), 6.29 (d, *J* = 10.8 Hz, 1H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.7.



**(1-cyclopropyl-3-phenylpropa-1,2-dien-1-yl)diphenylphosphine oxide (3o):** 26.5 mg (yield 37%), prepared from 68.9 mg of **1o** (0.4 mmol) and 40.4 mg of **2a** (0.2 mmol). This is a known compound.31H NMR (CDCl3, 400 MHz): *δ* =7.81–7.73 (m, 4H), 7.51–7.48 (m, 1H), 7.43–7.32 (m, 5H), 7.27–7.17 (m, 3H), 7.05 (d, *J* = 8.0 Hz, 2H), 6.16 (dd, *J1* = 10.8 Hz, *J2* = 1.2 Hz, 1H), 1.66–1.57 (m, 1H), 0.90–0.79 (m, 2H), 0.65–0.57 (m, 2H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.8.



**(4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)di-p-tolylphosphine oxide (3p):** 63.5 mg (yield 79%), prepared from 75.4 mg of **1a** (0.4 mmol) and 46.1 mg of **2b** (0.2 mmol). This is a known compound.3 1H NMR (CDCl3, 400 MHz): *δ* =7.62 (dd, *J1* = 11.6 Hz, *J2* = 8.0 Hz, 2H), 7.50 (dd, *J1* = 12.0 Hz, *J2* = 8.0 Hz, 2H), 7.24–7.17 (m, 5H), 7.01–7.99 (m, 4H), 6.00 (d, *J* = 10.8 Hz, 1H), 2.38 (s, 3H), 2.21 (s, 3H), 1.33 (s, 9H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.5.



**(4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)bis(4-fluorophenyl)phosphine oxide (3q):** 76.5 mg (yield 85%), prepared from 82.8 mg of **1a** (0.44 mmol) and 52.4 mg of **2c** (0.22 mmol). This is a known compound.31H NMR (CDCl3, 400 MHz): *δ* =7.77–7.71 (m, 2H), 7.63–7.57 (m, 2H), 7.27–7.20 (m, 3H), 7.16–7.11 (m, 2H), 7.00 (d, *J* = 8.0 Hz, 2H), 6.92-6.87 (m, 2H), 6.05 (d, *J*= 11.6 Hz, 1H), 1.33 (s, 9 H).31P NMR (CDCl3, 162 MHz): *δ* = 27.8.



**(4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)bis(4-methoxyphenyl)phosphine oxide (3r):** 77.5 mg (yield 90%), prepared from 75.2 mg of **1a** (0.4 mmol) and 52.5 mg of **2d** (0.2 mmol). This is a known compound.31H NMR (CDCl3, 400 MHz): *δ* =7.65 (dd, *J1* = 11.6 Hz, *J2* = 8.8 Hz, 2H), 7.53 (dd, *J1* = 11.6 Hz, *J2* = 8.8 Hz, 2H), 7.25–7.15 (m, 3H), 7.01 (d, *J* = 8.0 Hz, 2H), 6.93 (dd, *J1* = 8.8 Hz, *J2* = 2.0 Hz, 2H), 6.69 (dd, *J1* = 8.8 Hz, *J2* = 2.4 Hz, 2H), 6.00 (d, *J*= 11.2 Hz, 1H), 3.83 (s, 3H) 3.67 (s, 3H), 1.33 (s, 9 H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.8.



**bis(3-chlorophenyl)(4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)phosphine oxide (3s):** 75.2 mg (yield 82%), prepared from 75.3 mg of **1a** (0.4 mmol) and 54.2 mg of **2e** (0.2 mmol). This is a known compound.31H NMR (CDCl3, 400 MHz): *δ* =7.74 (dt, *J1* = 12.0 Hz, *J*2= 1.6 Hz, 1H), 7.64–7.56 (m, 2H), 7.51–7.36 (m, 3H), 7.29–7.13 (m, 5H), 7.03 (d, *J* = 8.0 Hz, 1H), 6.11 (d, *J* = 11.2 Hz, 1H), 1.34 (s, 9H). 31P NMR (CDCl3, 162 MHz): *δ* = 27.3.



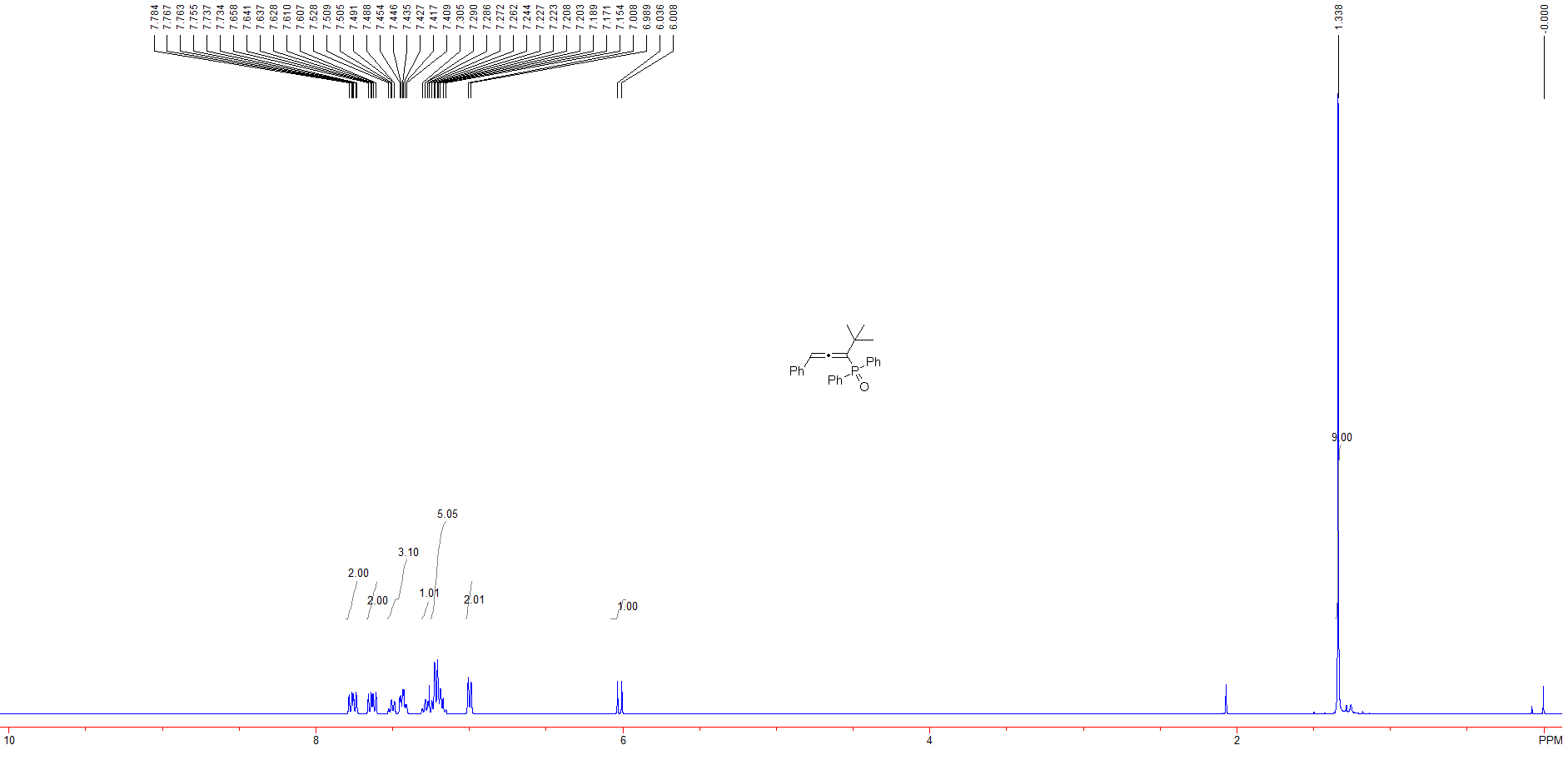
**(4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)bis(4-methoxyphenyl)phosphine oxide (3t):** 63.9 mg (yield 82%), prepared from 75.4 mg of **1a** (0.4 mmol) and 44.0 mg of **2f** (0.2 mmol). 1H NMR (CDCl3, 400 MHz): *δ* =7.79-7.57 (m, 4H), 7.54-7.31 (m, 2H), 7.26–7.17 (m, 4H), 7.13-7.08 (m, 1H), 7.03-6.98 (m, 2H), 6.89-6.84 (m, 1H), 6.06-6.01 (m, 1H), 1.34 (s, 4.5H), 1.33 (s, 4.5H). 31P NMR (CDCl3, 162 MHz): *δ* = 29.13, 29.08. HRMS (ESI-TOF): *m/z* = 391.1618, calcd for C25H25FOP [MH+] 391.1627.



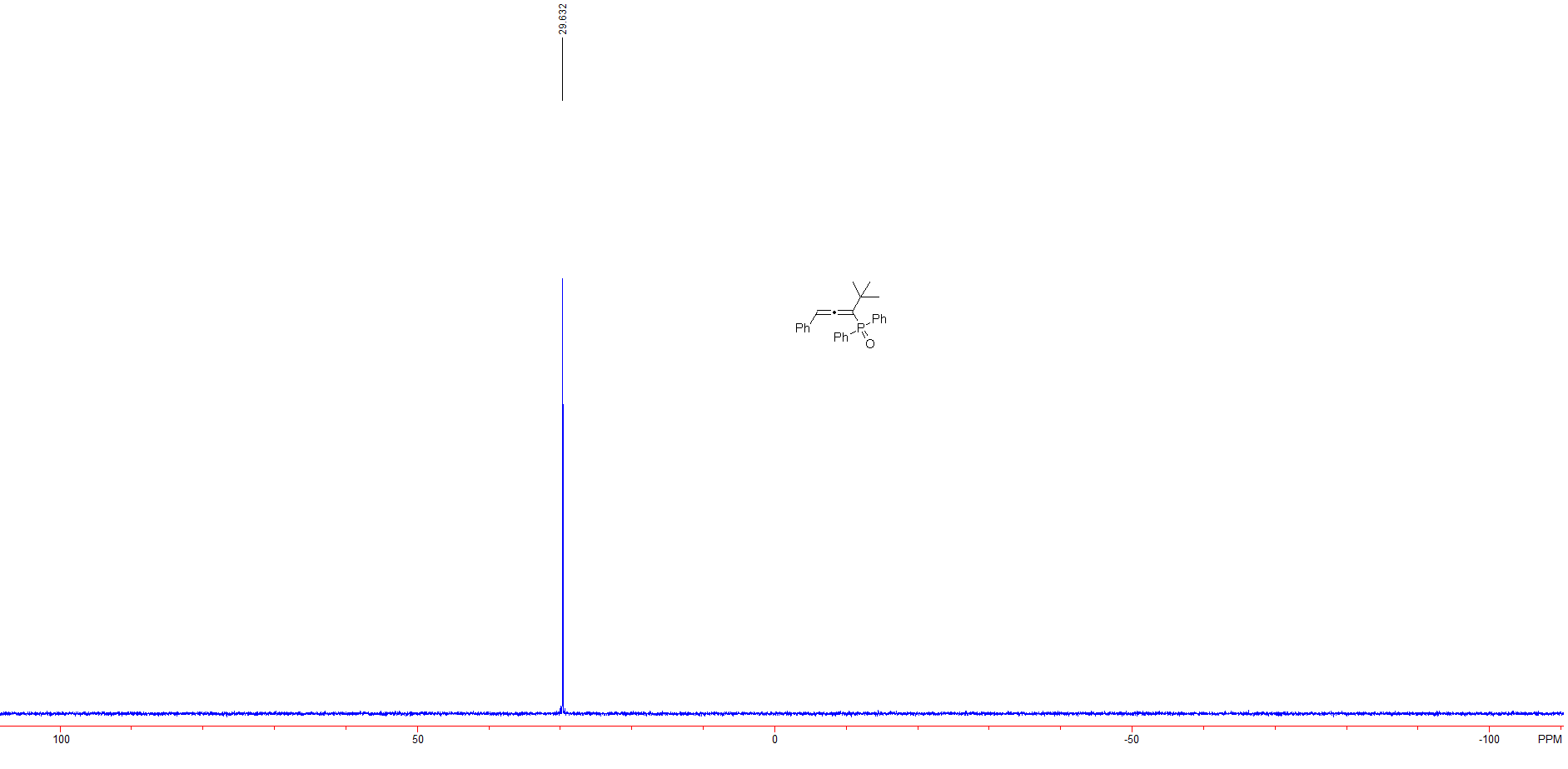
**(4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)bis(4-methoxyphenyl)phosphine oxide (3u):** 67.8 mg (yield 84%), prepared from 75.5 mg of **1a** (0.4 mmol) and 46.4 mg of **2g** (0.2 mmol). 1H NMR (CDCl3, 400 MHz): *δ* =7.77-7.39 (m, 6H), 7.25-7.161 (m, 4H), 7.02–6.93 (m, 3H), 6.72-6.69 (m, 1H), 6.03-5.99 (m, 1H), 3.84 (s, 1.5H), 3.68 (s, 1.5), 1.33 (s, 9 H). 31P NMR (CDCl3, 162 MHz): *δ* = 30.1, 29.9. HRMS (ESI-TOF): *m/z* = 403.1819, calcd for C26H28O2P [MH+] 403.1827.

Reference:

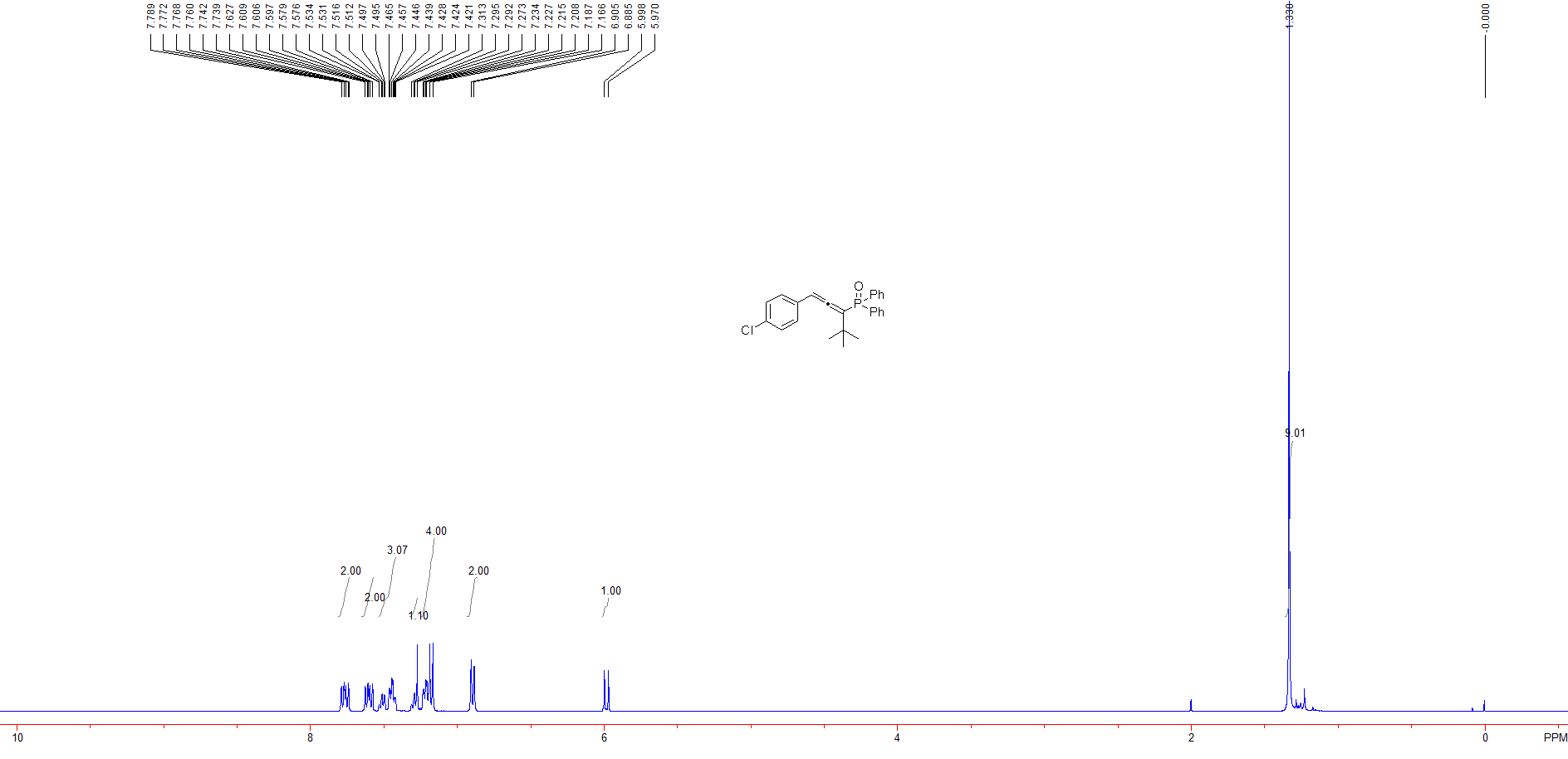
1. J. Y. Kang, B. T. Connell, *J. Org. Chem.* **2011**, *76*, 2379.
2. R. Shen, B. Luo, J. Yang, L. Zhang and L.-B. Han, *Chem. Commun.* **2016**, *52*, 6451.
3. (a) G. Hu, C. Shan, W. Chen, P. Xu, Y. Gao and Y. Zhao, *Org. Lett*. **2016**, *18*, 6066; (b) J. Yang, M. Zhang, K. Qiu, L. Wang, J. Yu, Z. Xia, R. Shen, L.-B. Han, *Adv. Syn. Catal.* **2017**, *359*, 4417.



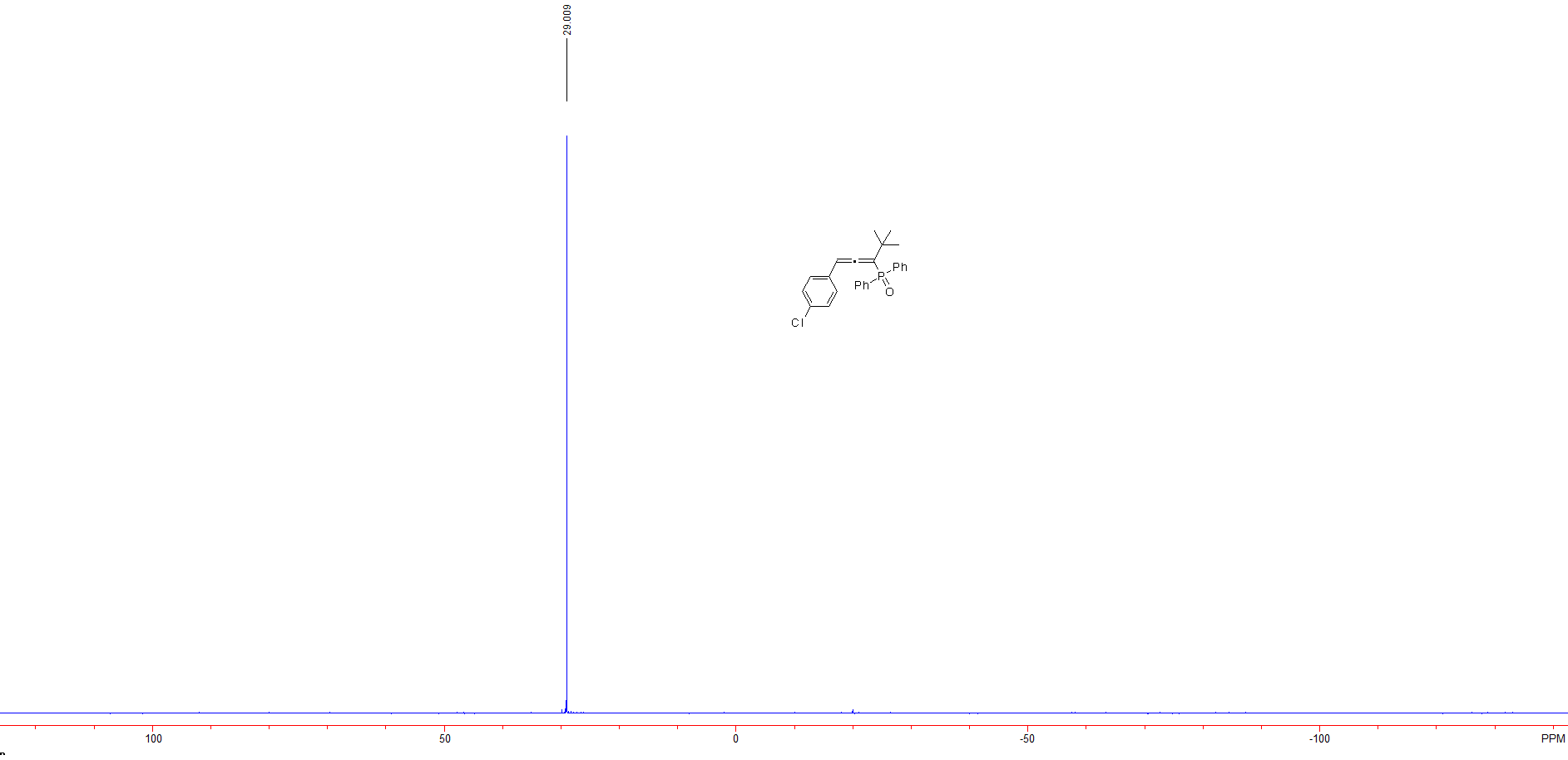
**Figure S 2:** 1H NMR spectra of (4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)diphenylphosphine oxide (**3a**)



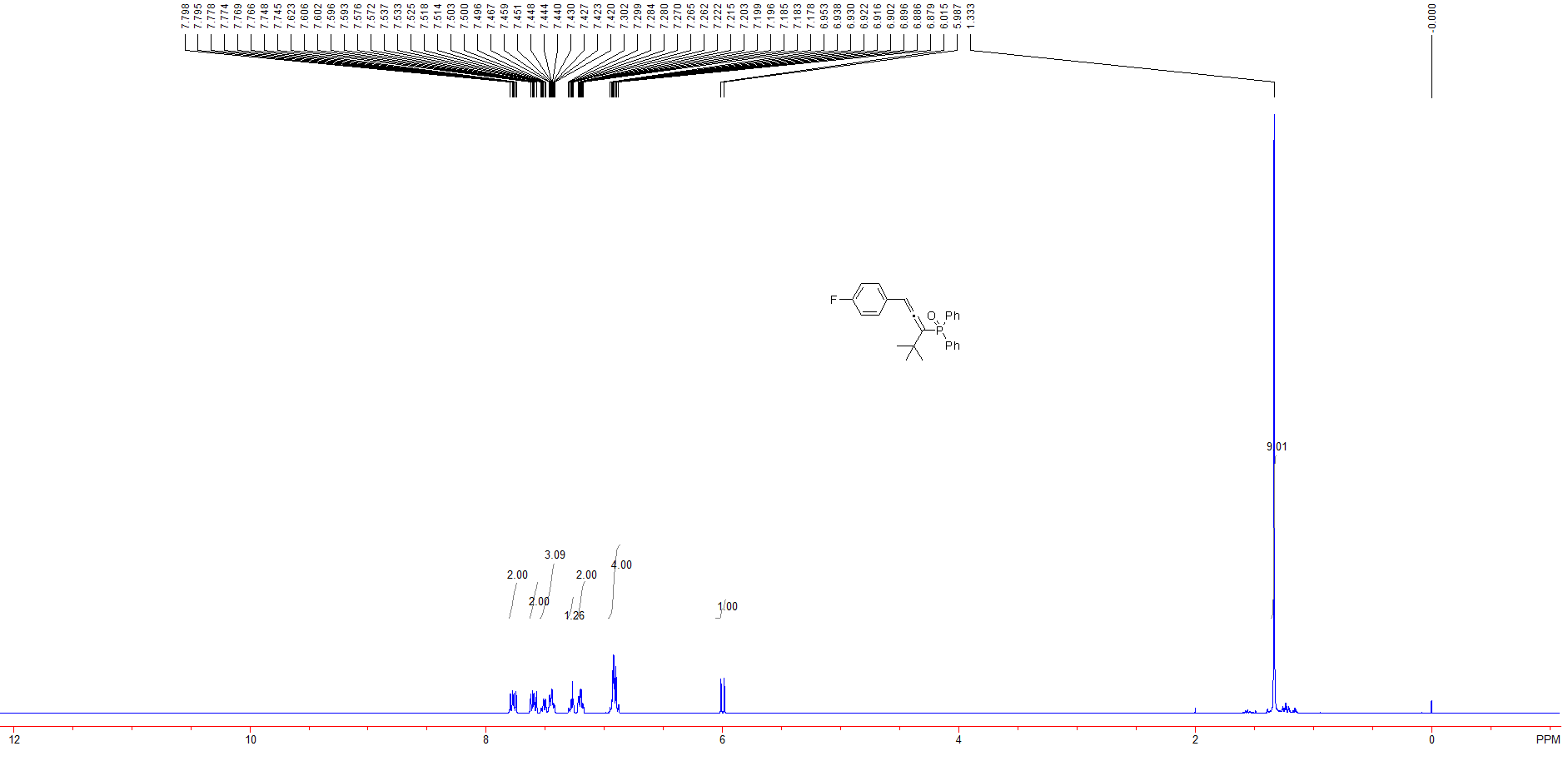
**Figure S 3:** 31P NMR spectra of (4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)diphenylphosphine oxide (**3a**)



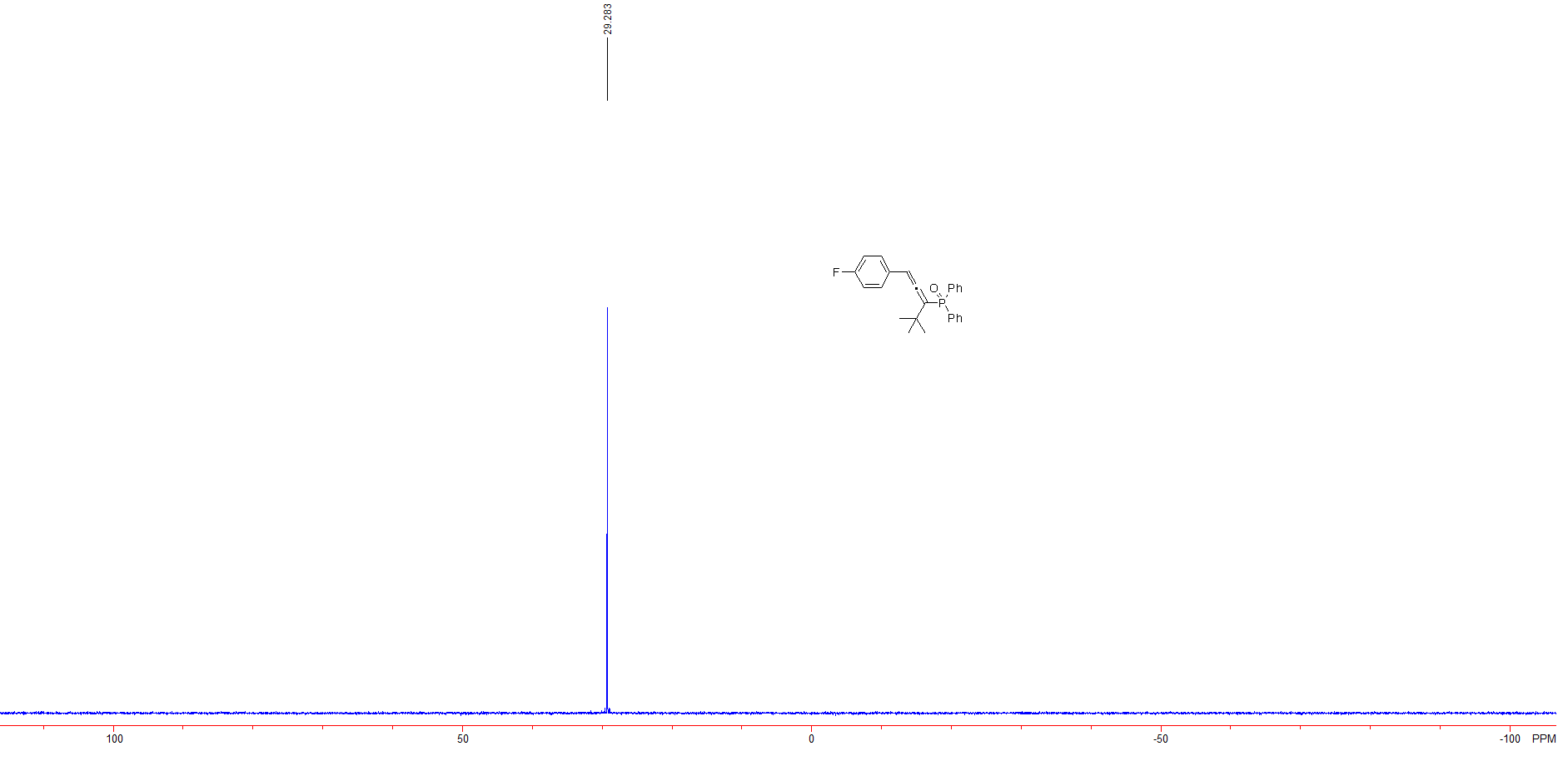
**Figure S 4:** 1H NMR spectra of (1-(4-chlorophenyl)-4,4-dimethylpenta-1,2-dien-3-yl)diphenylphosphine oxide (**3b**)



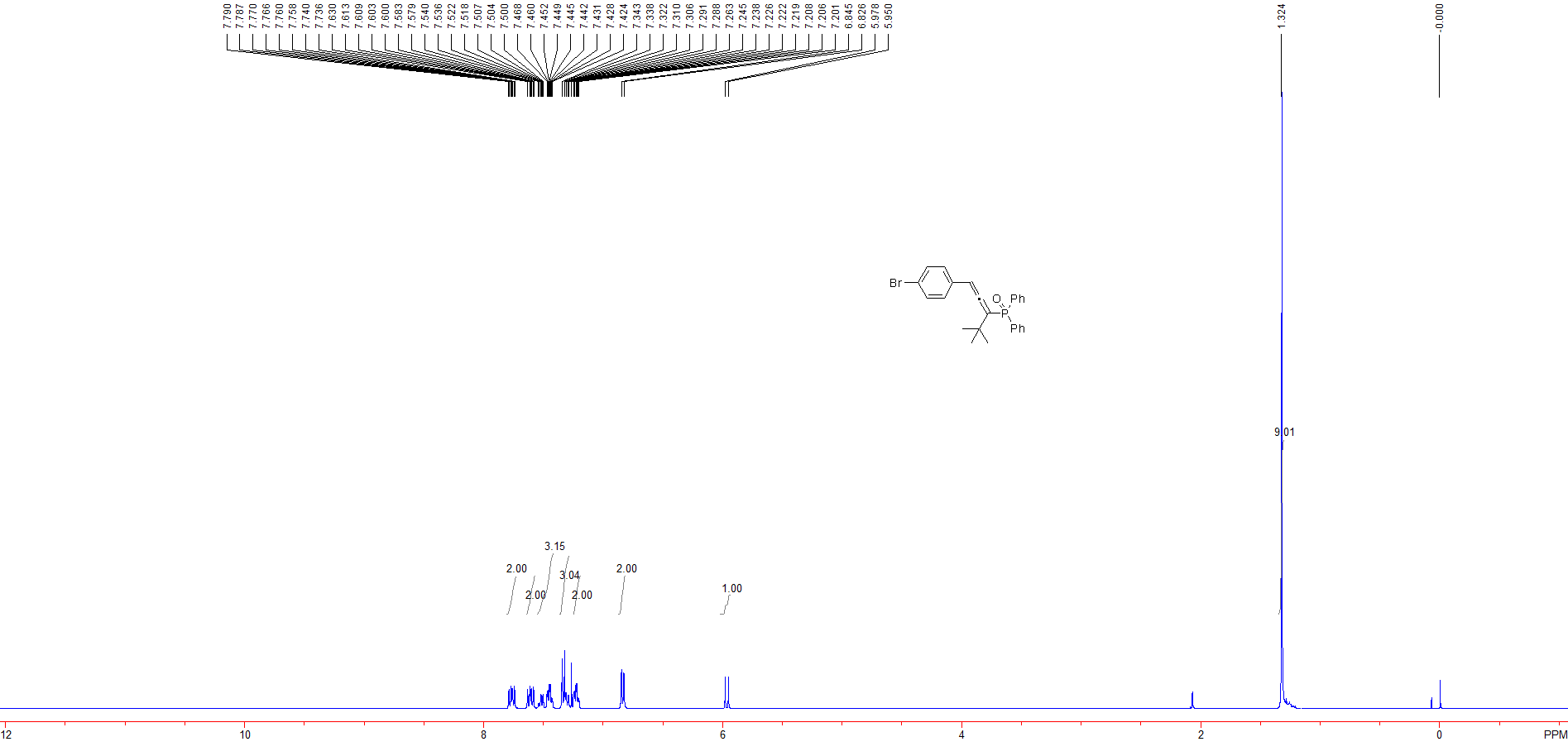
**Figure S 5:** 31P NMR spectra of (1-(4-chlorophenyl)-4,4-dimethylpenta-1,2-dien-3-yl)diphenylphosphine oxide (**3b**)



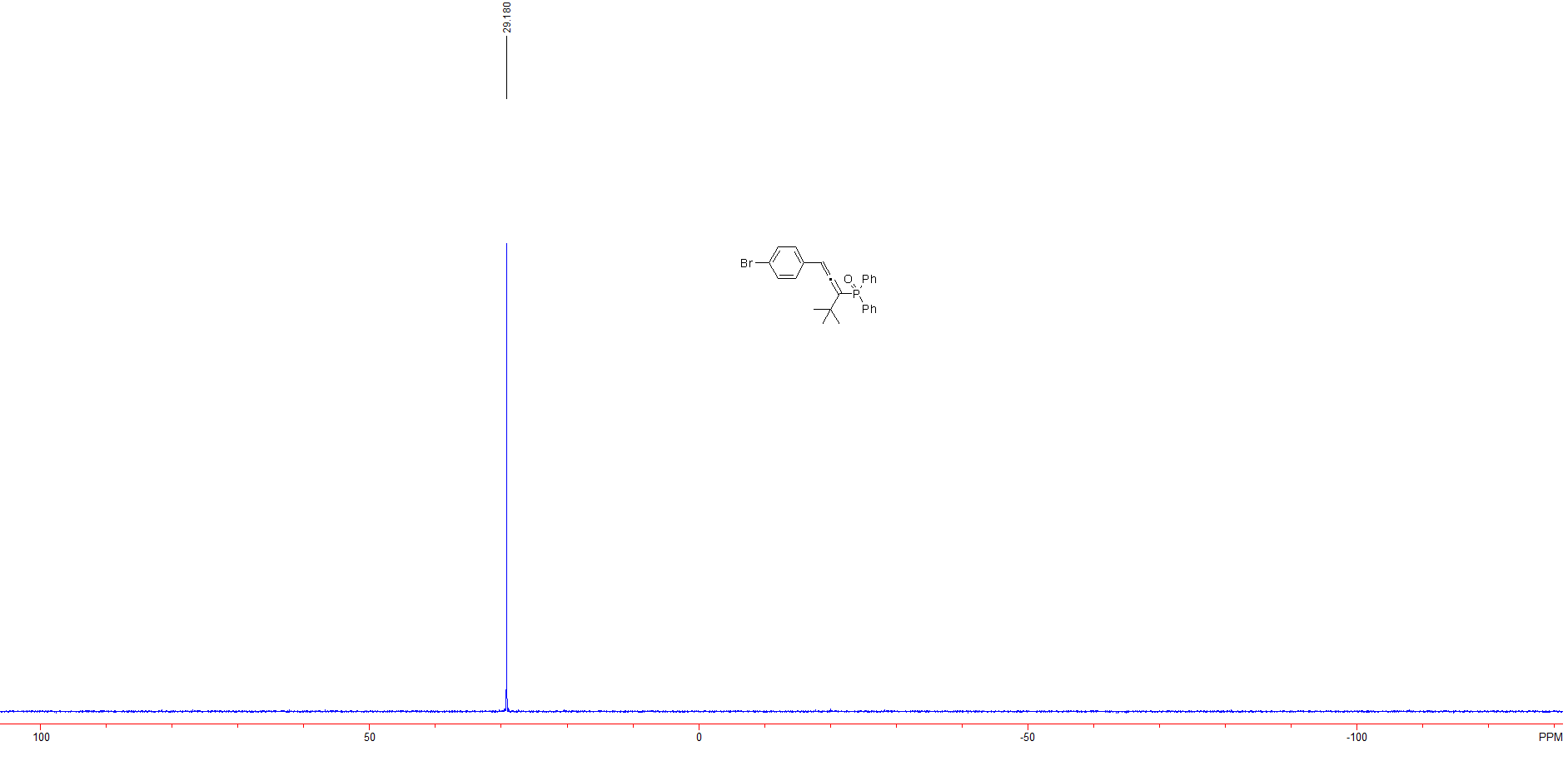
**Figure S 6:** 1H NMR spectra of (1-(4-fluorophenyl)-4,4-dimethylpenta-1,2-dien-3-yl)diphenylphosphine oxide (**3c**)



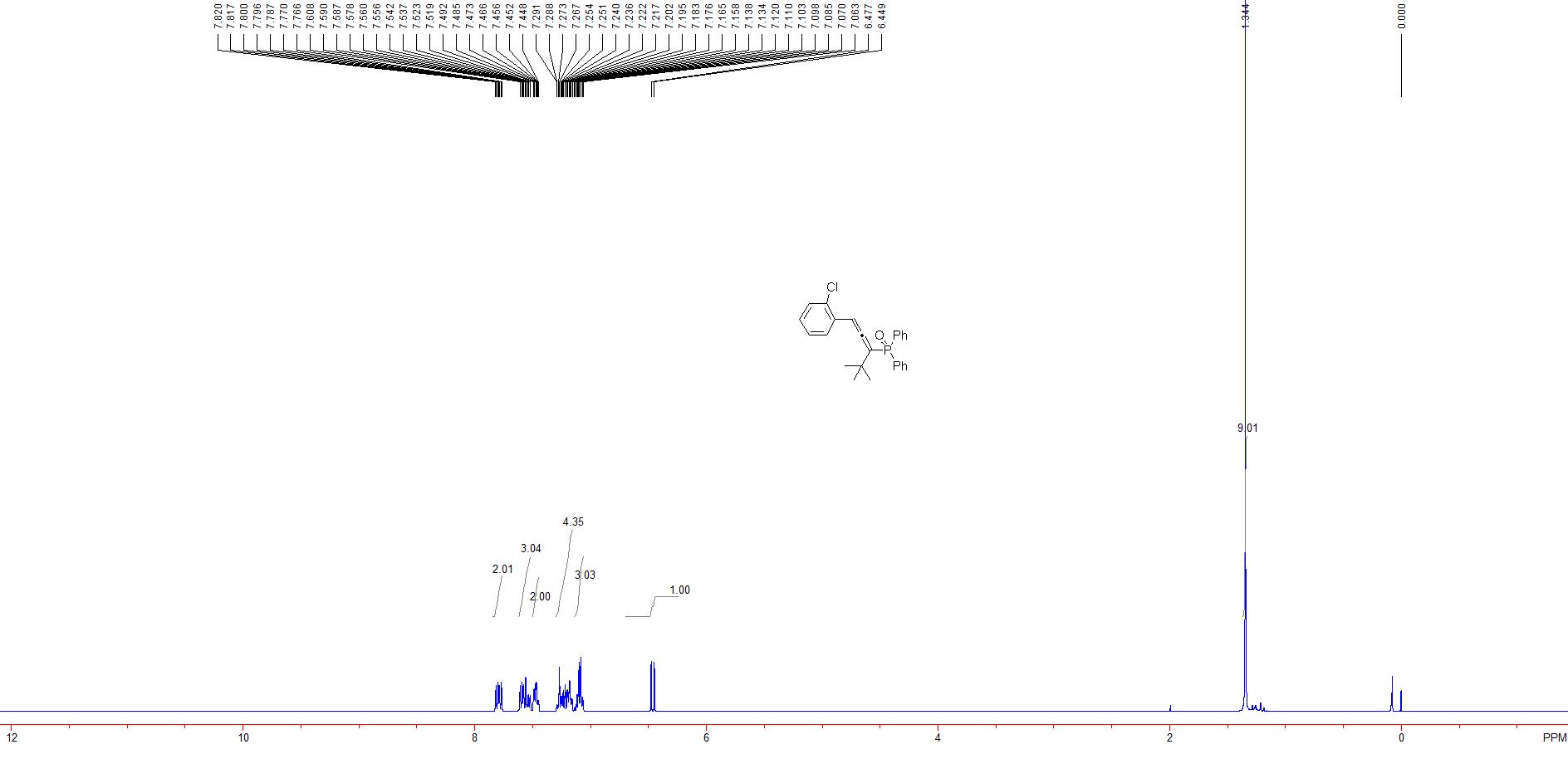
**Figure S 7:** 31P NMR spectra of (1-(4-fluorophenyl)-4,4-dimethylpenta-1,2-dien-3-yl)diphenylphosphine oxide (**3c**)



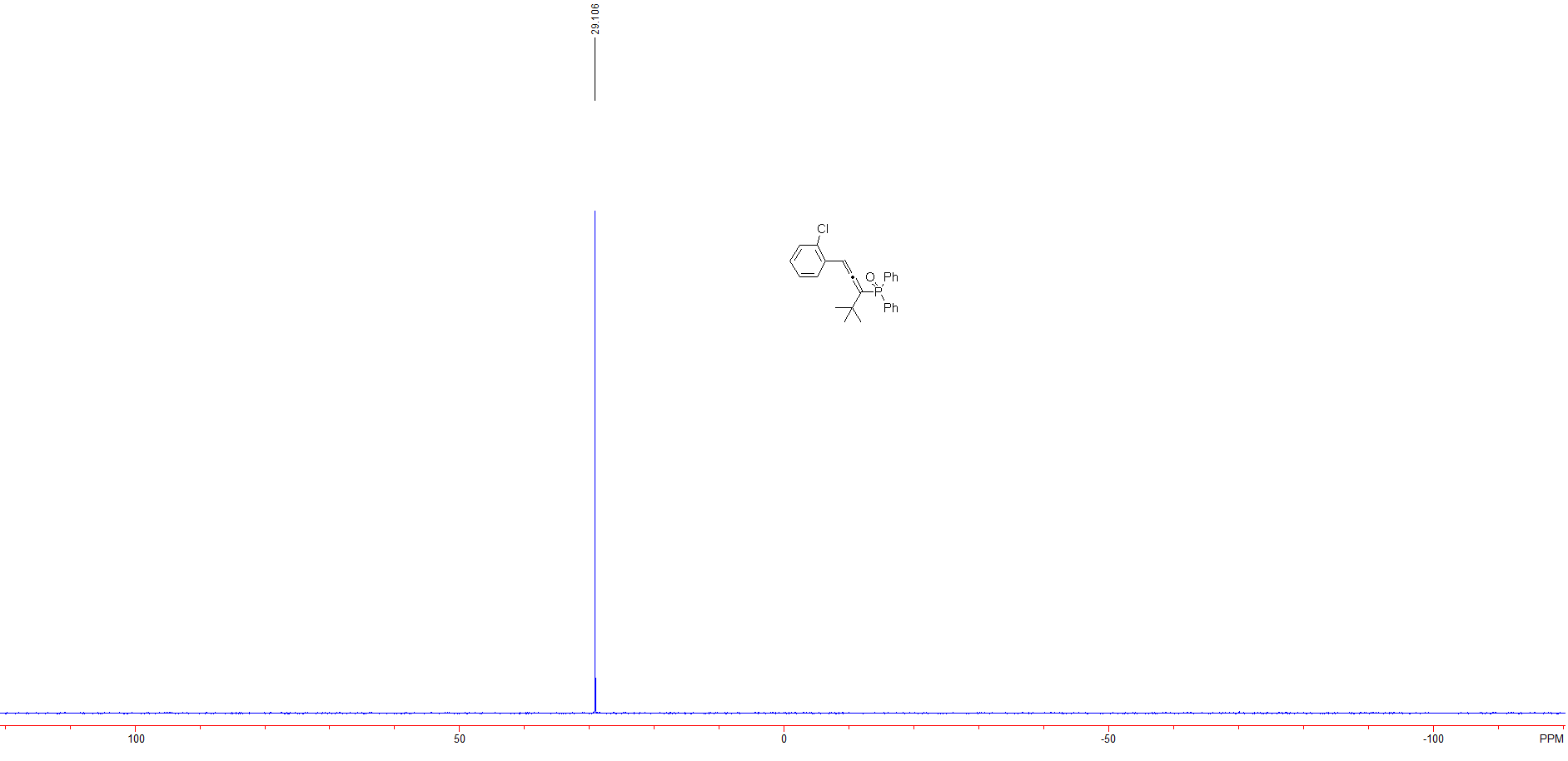
**Figure S 8:** 1H NMR spectra of (1-(4-bromophenyl)-4,4-dimethylpenta-1,2-dien-3-yl)diphenylphosphine oxide (**3d**)



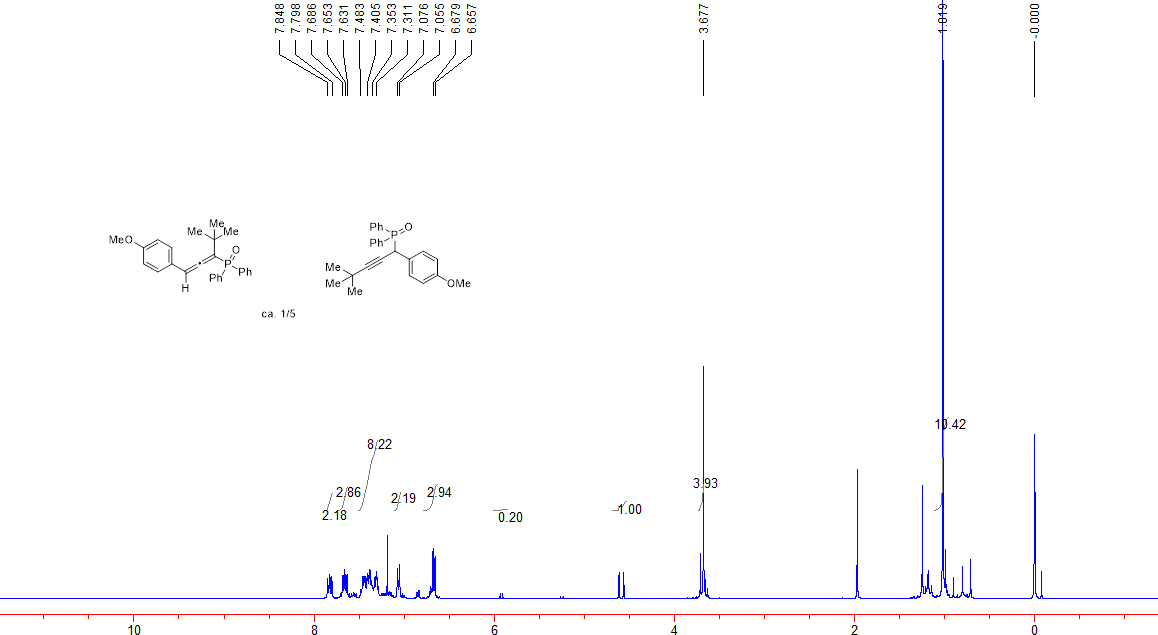
**Figure S 9:** 31P NMR spectra of (1-(4-bromophenyl)-4,4-dimethylpenta-1,2-dien-3-yl)diphenylphosphine oxide (**3d**)



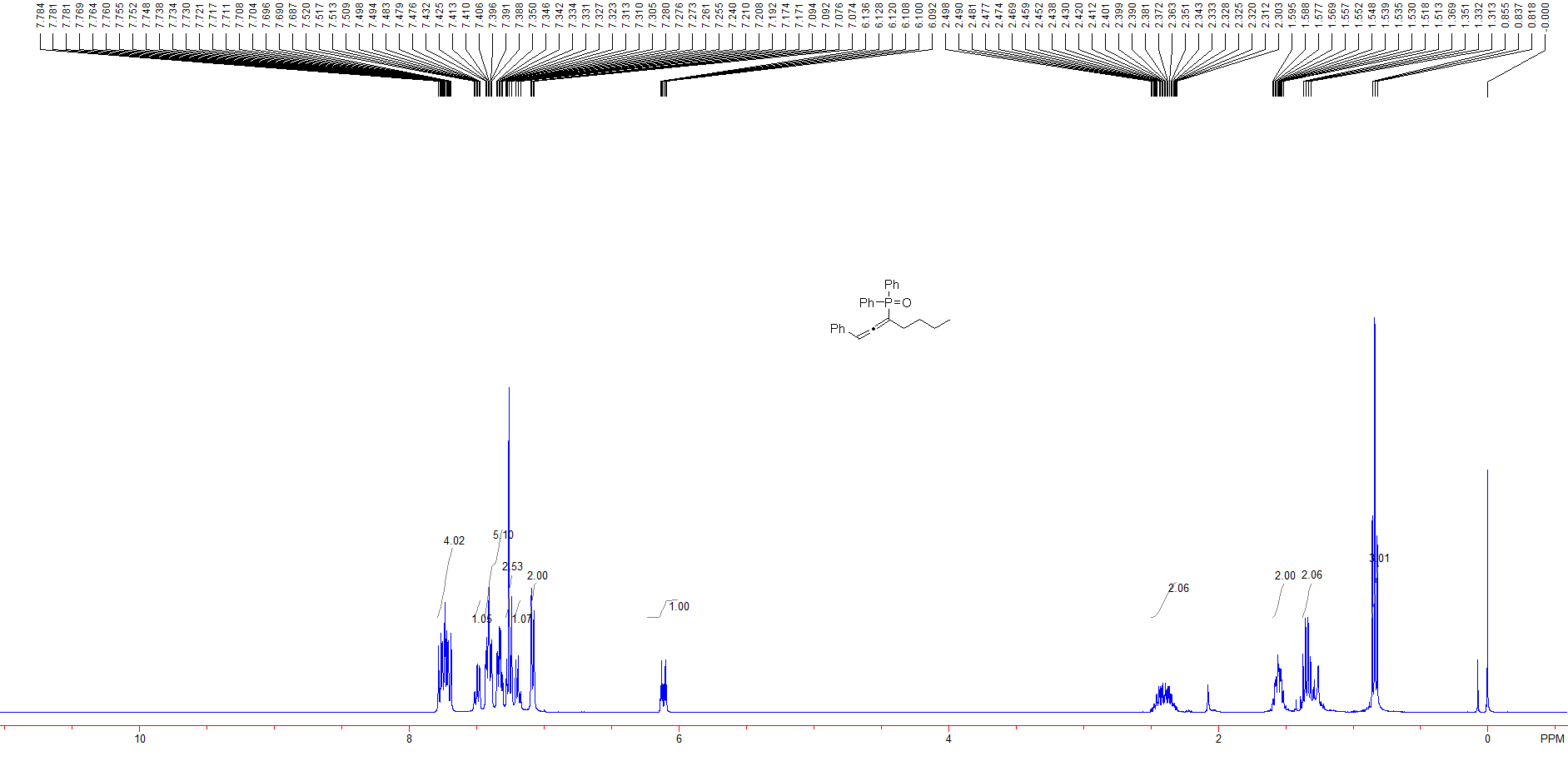
**Figure S 10:** 1H NMR spectra of (1-(2-chlorophenyl)-4,4-dimethylpenta-1,2-dien-3-yl)diphenylphosphine oxide (**3e**)



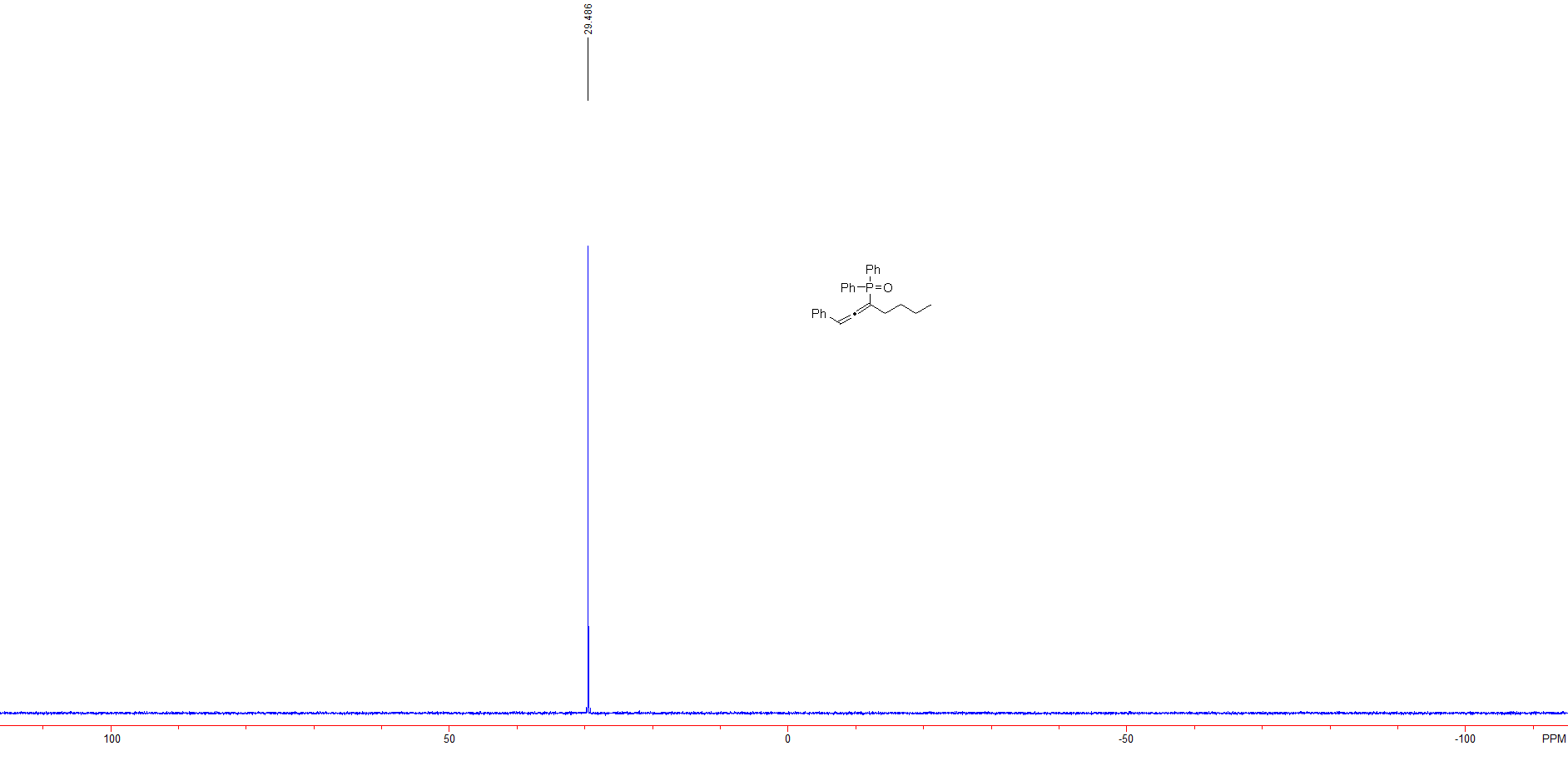
**Figure S 11:** 31P NMR spectra of (1-(2-chlorophenyl)-4,4-dimethylpenta-1,2-dien-3-yl)diphenylphosphine oxide (**3e**)



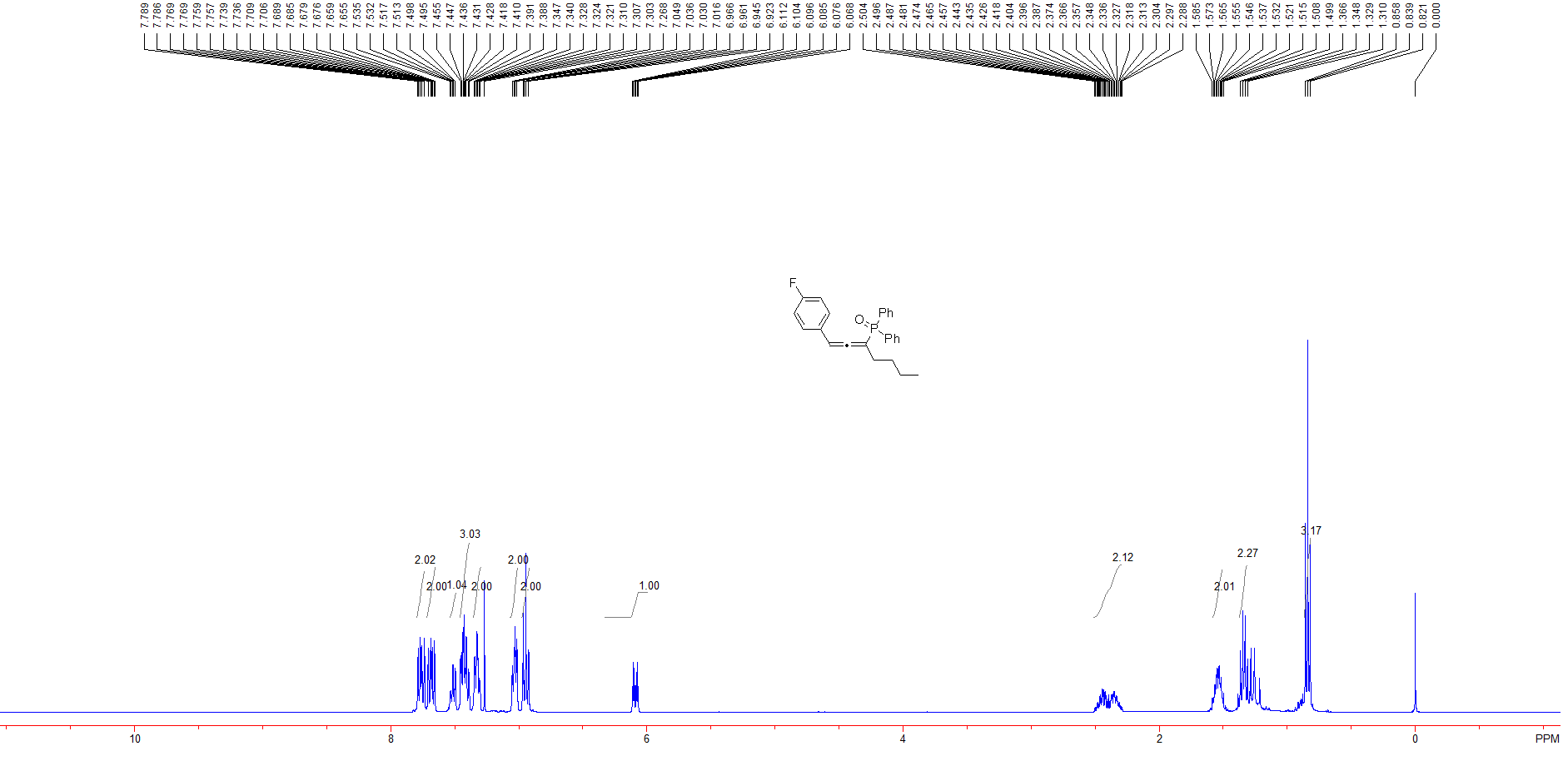
**Figure S 12:** 1H NMR spectra of the mixture of (1-(4-methoxyphenyl)-4,4-dimethylpenta-1,2-dien-3-yl)diphenylphosphineoxide(3f)and(1-(4-methoxyphenyl)-4,4-dimethylpent-2-yn-1-yl)diphenylphosphineoxide (**3f’**)



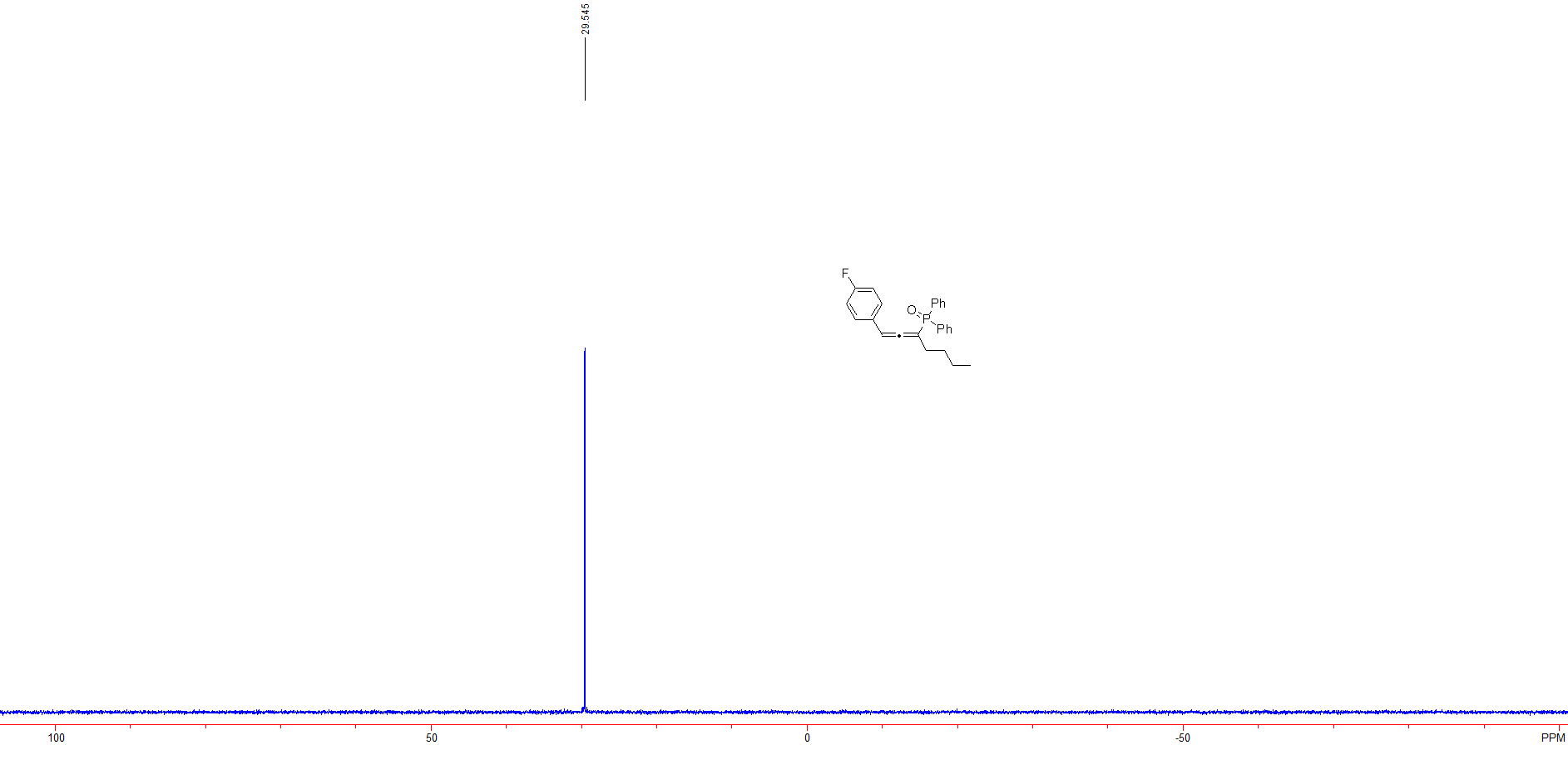
**Figure S 13:** 1H NMR spectra of diphenyl(1-phenylhepta-1,2-dien-3-yl)phosphine oxide (**3g**)



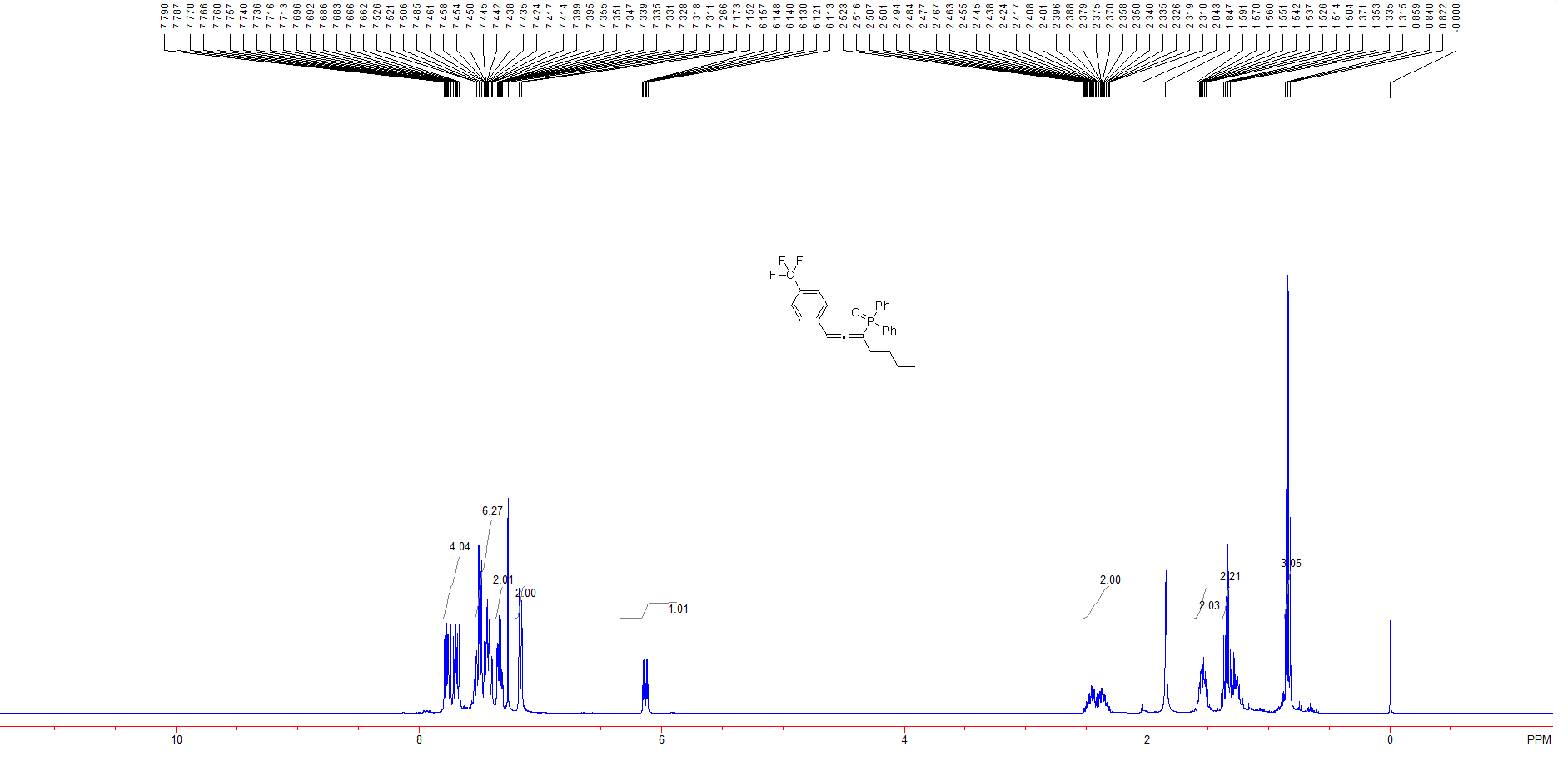
**Figure S 14:** 31P NMR spectra of diphenyl(1-phenylhepta-1,2-dien-3-yl)phosphine oxide (**3g**)



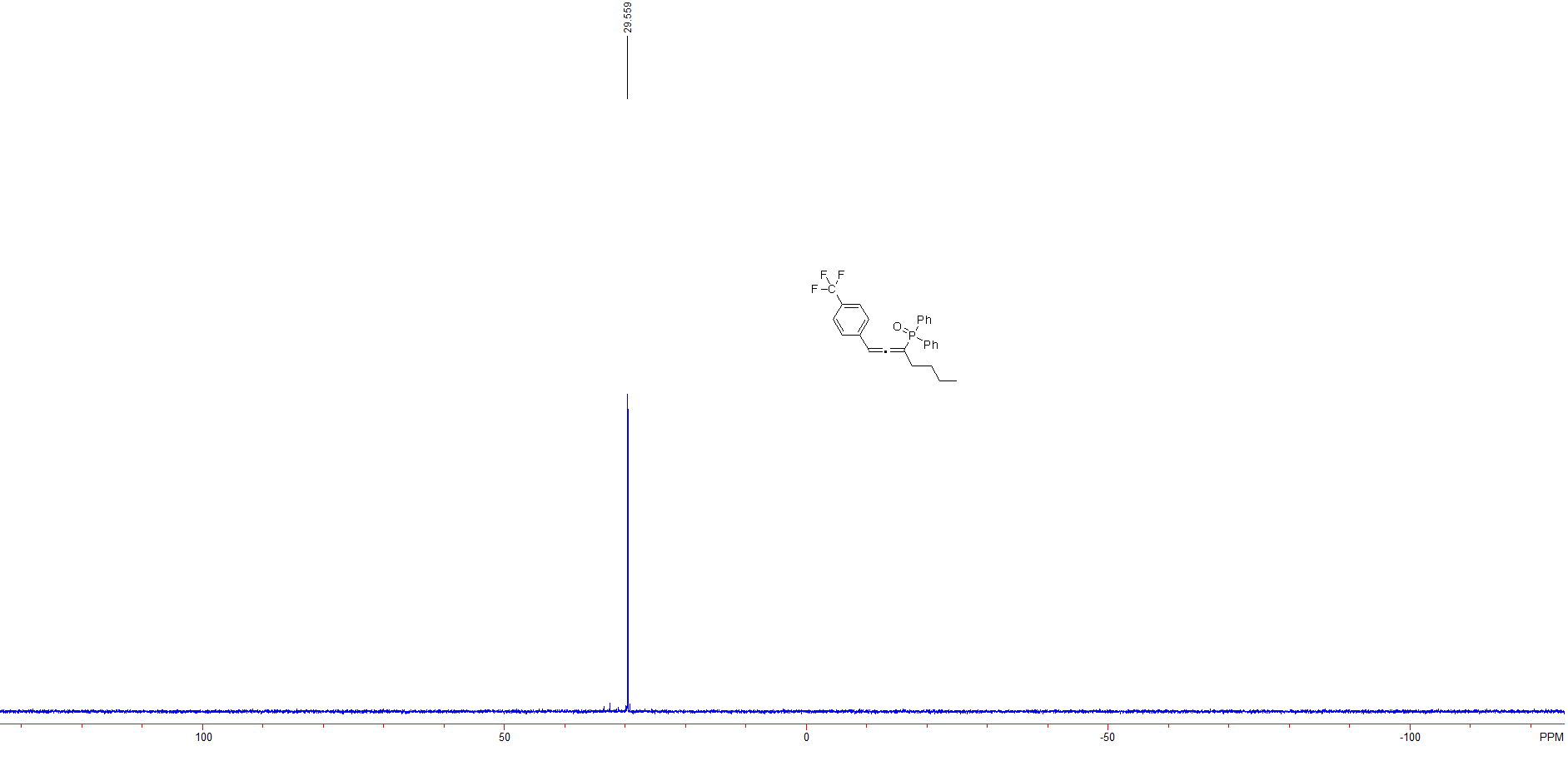
**Figure S 15:** 1H NMR spectra of (1-(4-fluorophenyl)hepta-1,2-dien-3-yl)diphenylphosphine oxide (**3h**)



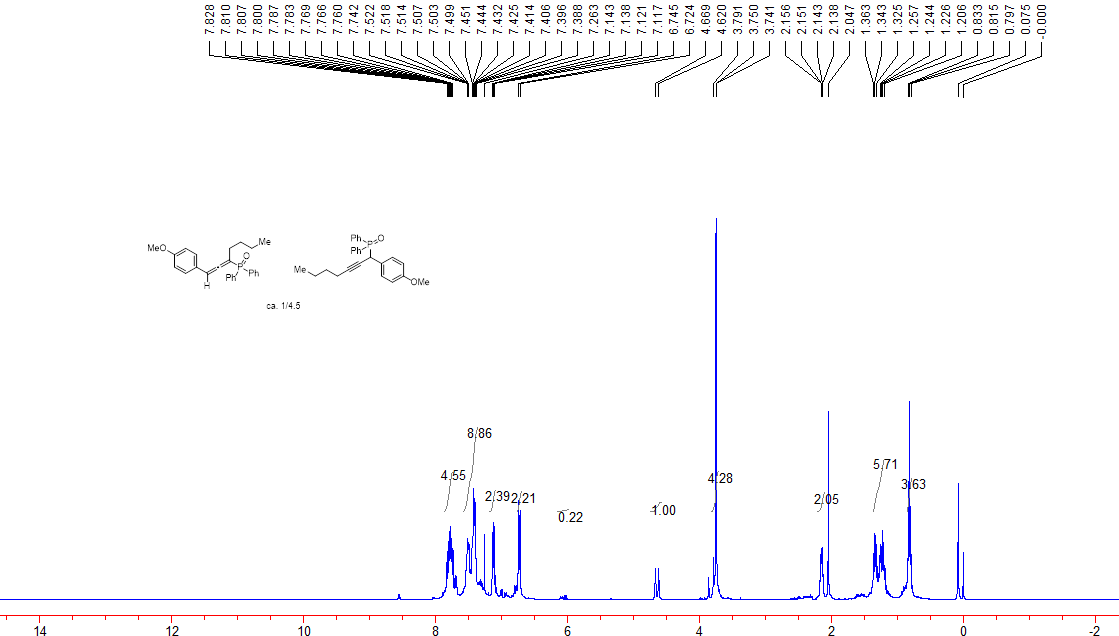
**Figure S 16:** 31P NMR spectra of (1-(4-fluorophenyl)hepta-1,2-dien-3-yl)diphenylphosphine oxide (**3h**)



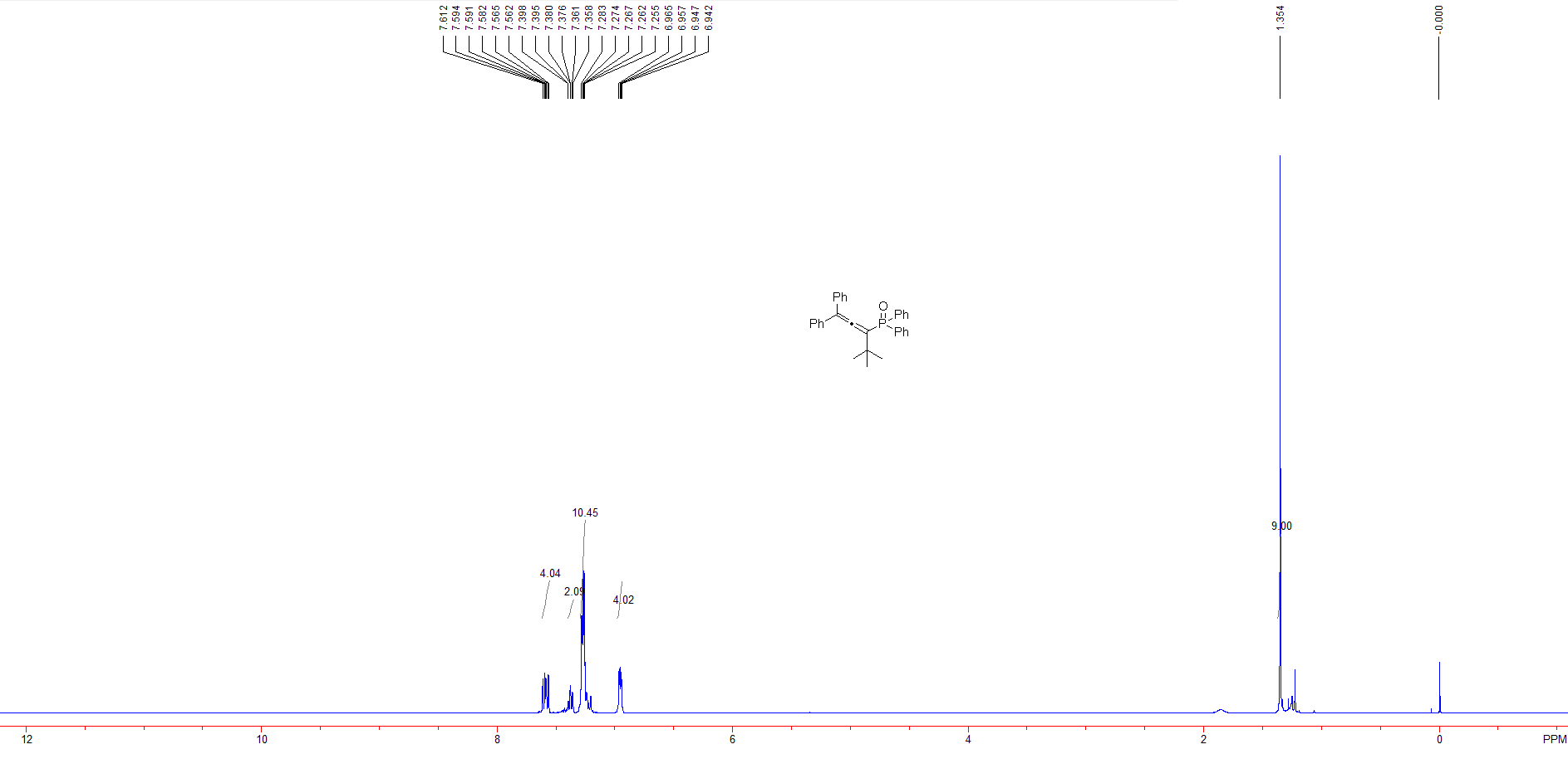
**Figure S 17:** 1H NMR spectra of diphenyl(1-(4-(trifluoromethyl)phenyl)hepta-1,2-dien-3-yl)phosphine oxide (**3i**)

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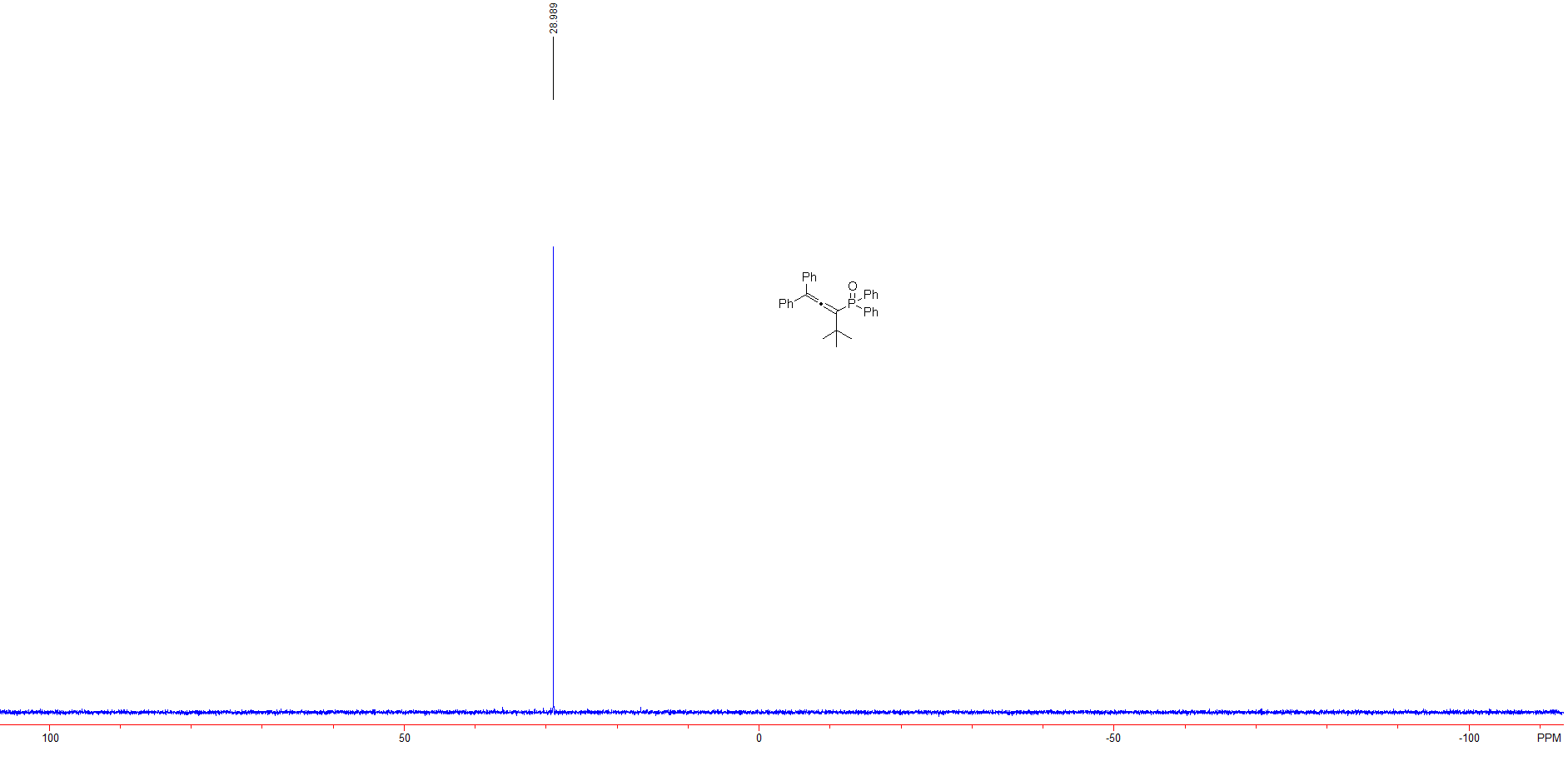
**Figure S 18:** 31P NMR spectra of diphenyl(1-(4-(trifluoromethyl)phenyl)hepta-1,2-dien-3-yl)phosphine oxide (**3i**)

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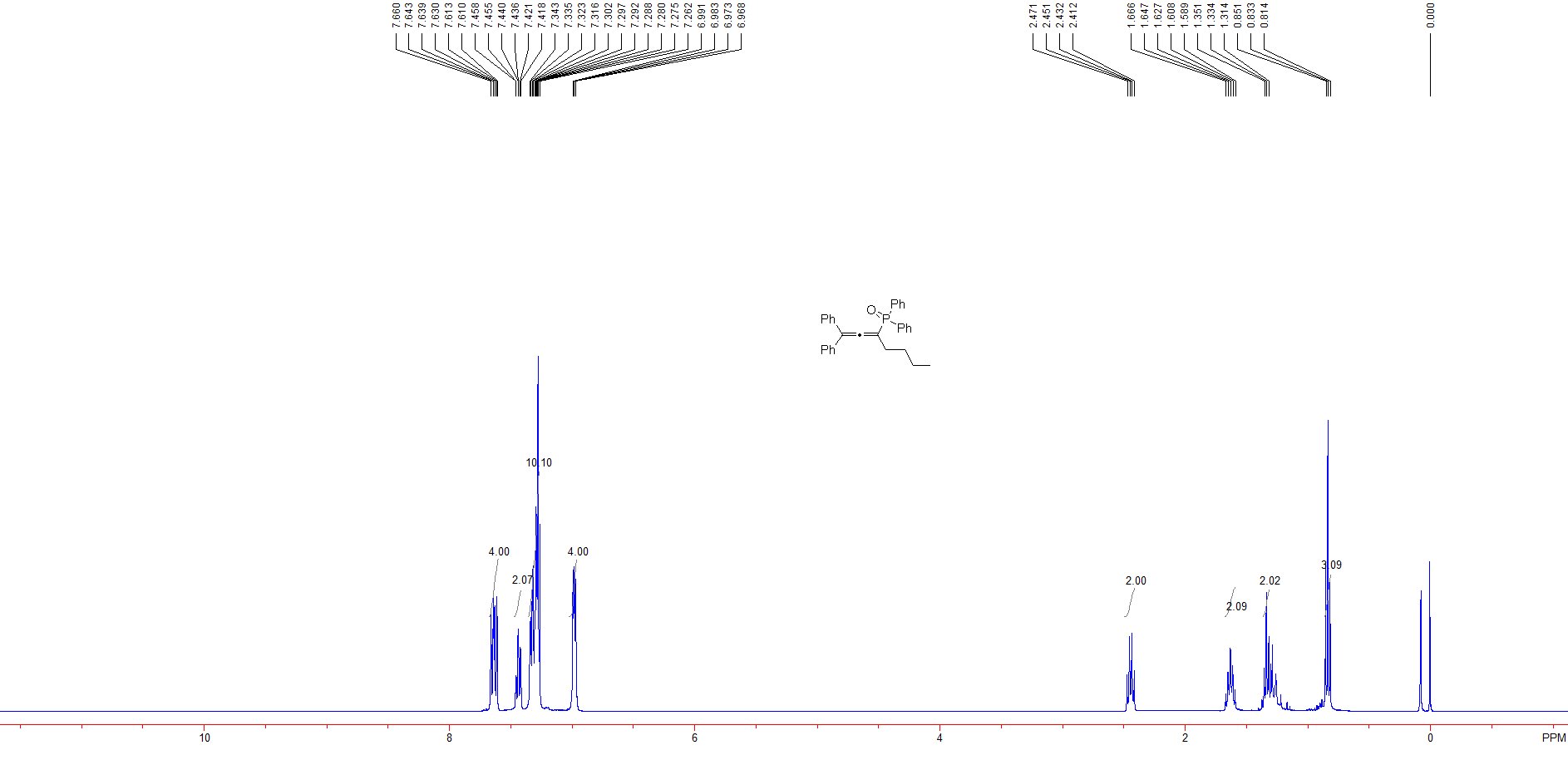
**Figure S 19:** 1H NMR spectra of the mixture of (1-(4-methoxyphenyl)hepta-1,2-dien-3-yl)diphenylphosphine oxide (**3j**) and (1-(4-methoxyphenyl)hepta-1,2-dien-3-yl)diphenylphosphine oxide (**3j’**)



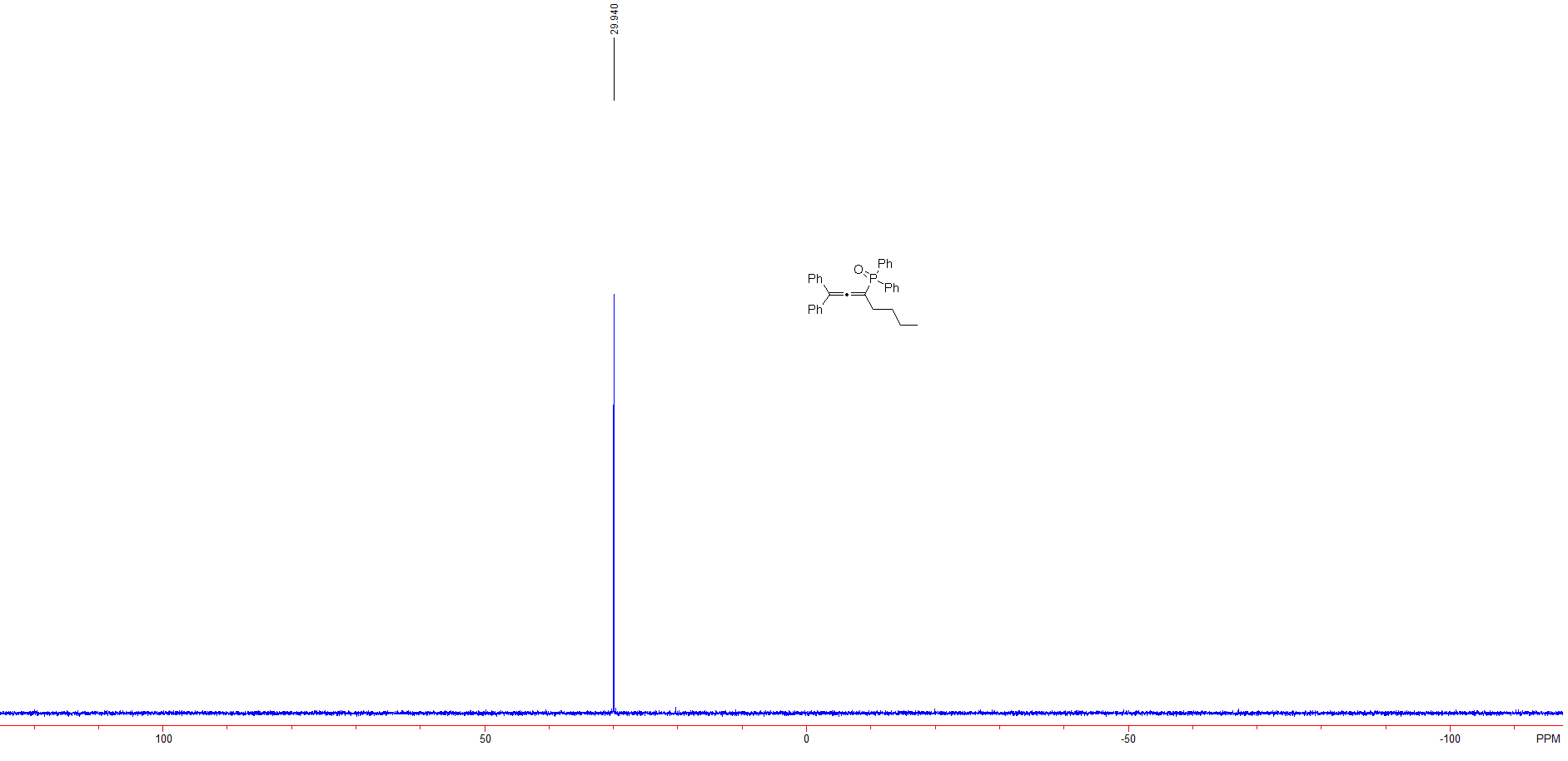
**Figure S 20:** 1H NMR spectra of (4,4-dimethyl-1,1-diphenylpenta-1,2-dien-3-yl)diphenylphosphine oxide (**3k**)



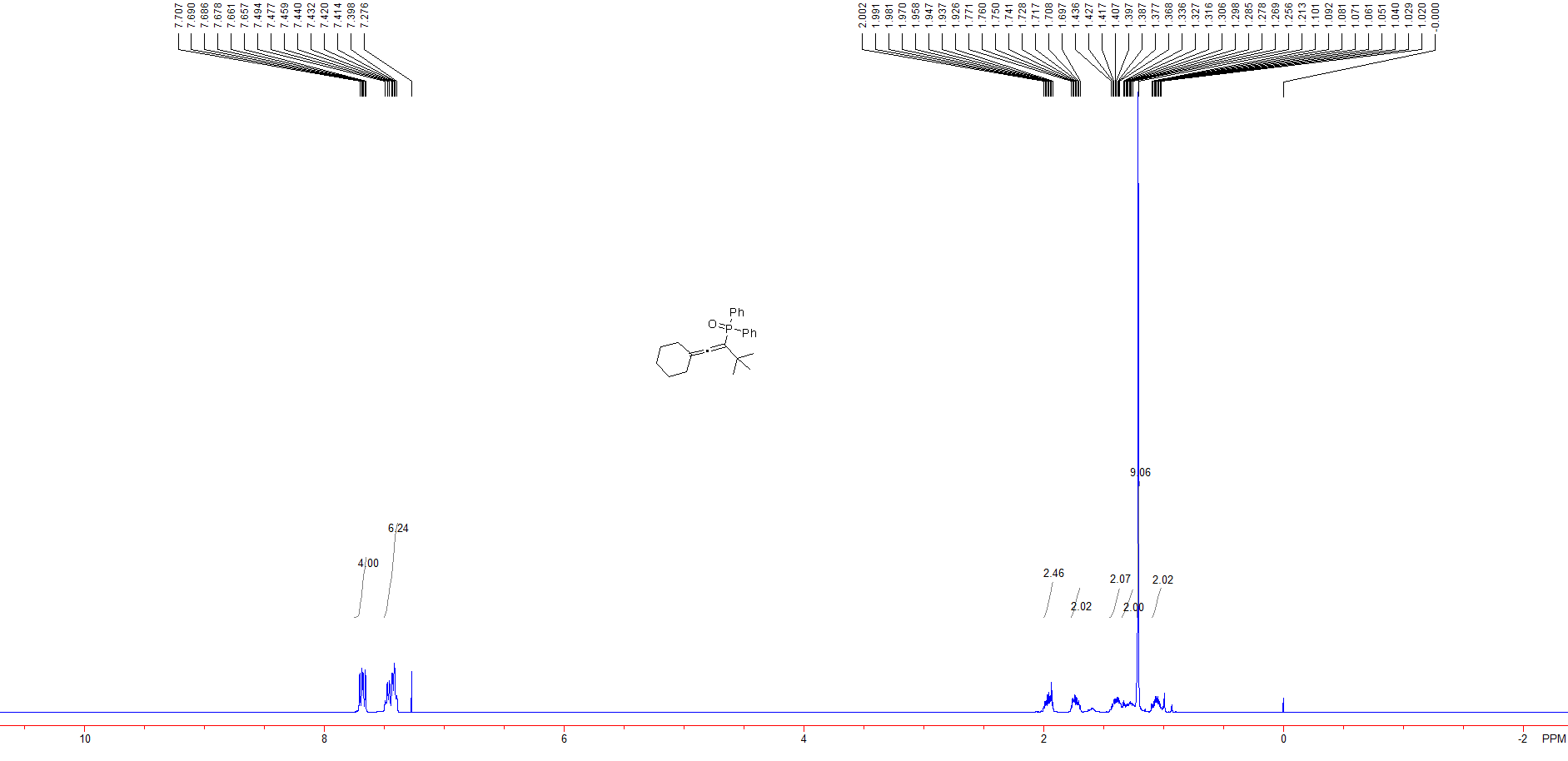
**Figure S 21:** 31P NMR spectra of (4,4-dimethyl-1,1-diphenylpenta-1,2-dien-3-yl)diphenylphosphine oxide (**3k**)

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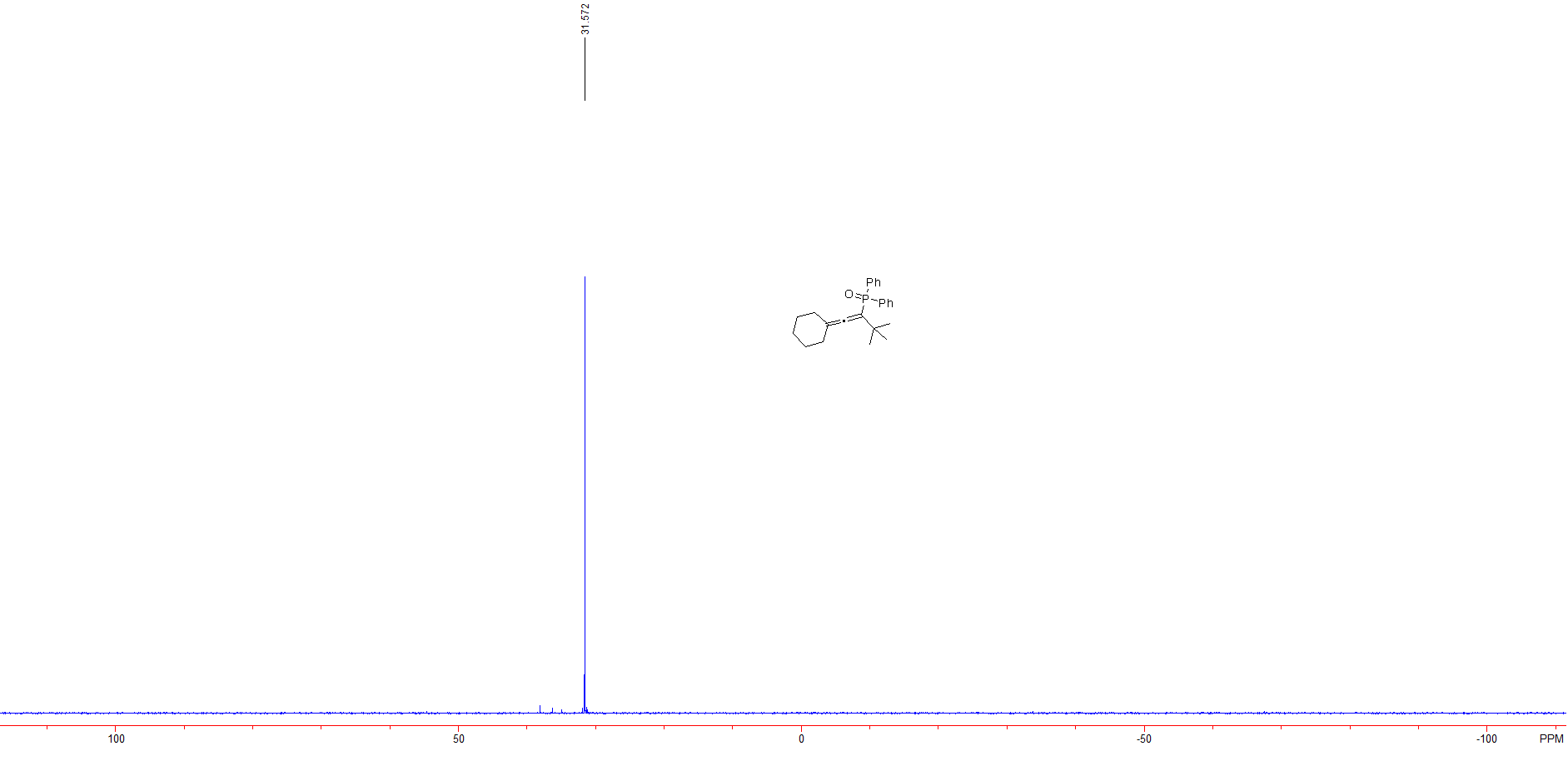
**Figure S 22:** 1H NMR spectra of (1,1-diphenylhepta-1,2-dien-3-yl)diphenylphosphine oxide (**3l**)



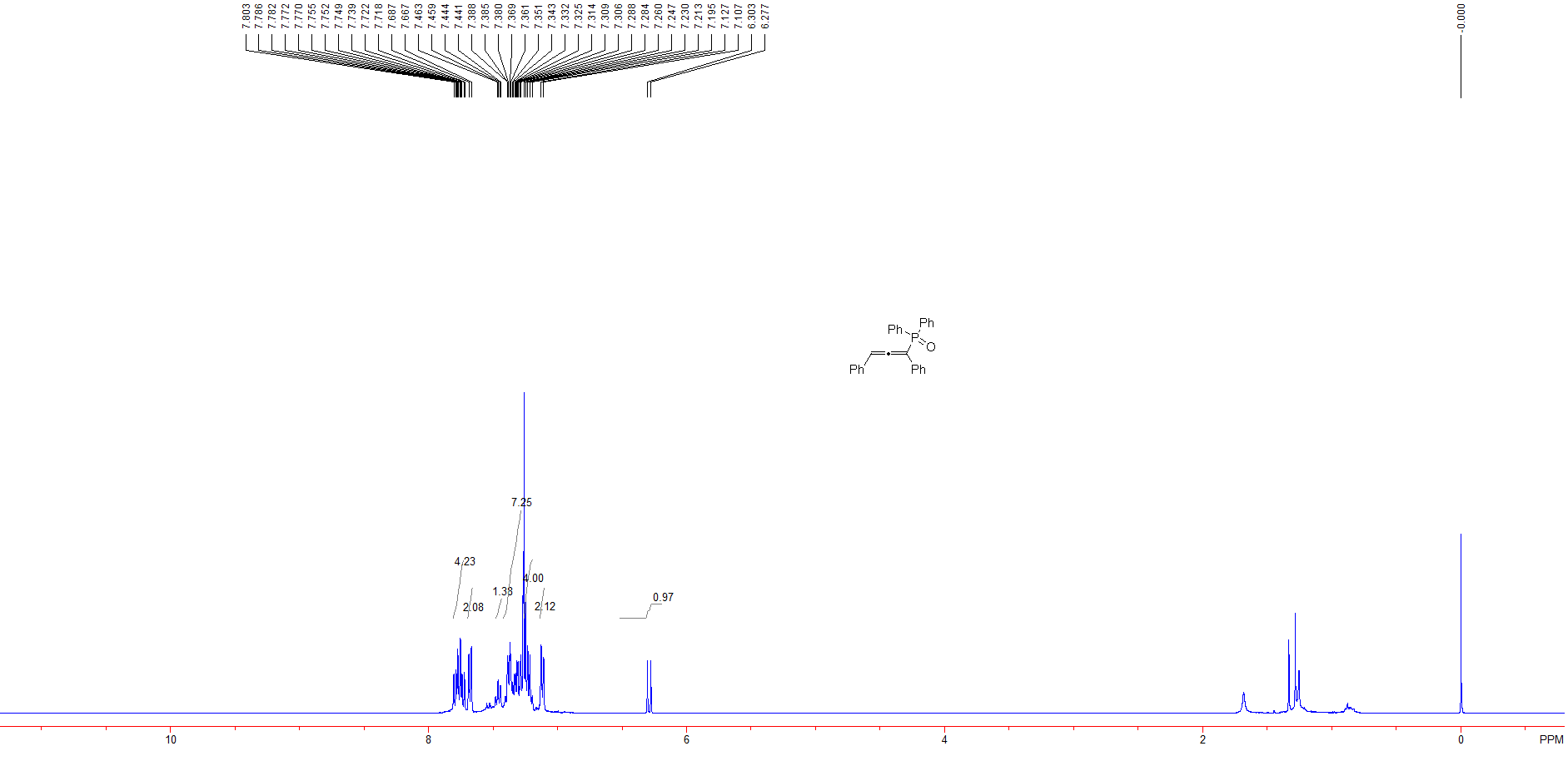
**Figure S 23:** 31P NMR spectra of (1,1-diphenylhepta-1,2-dien-3-yl)diphenylphosphine oxide (**3l**)



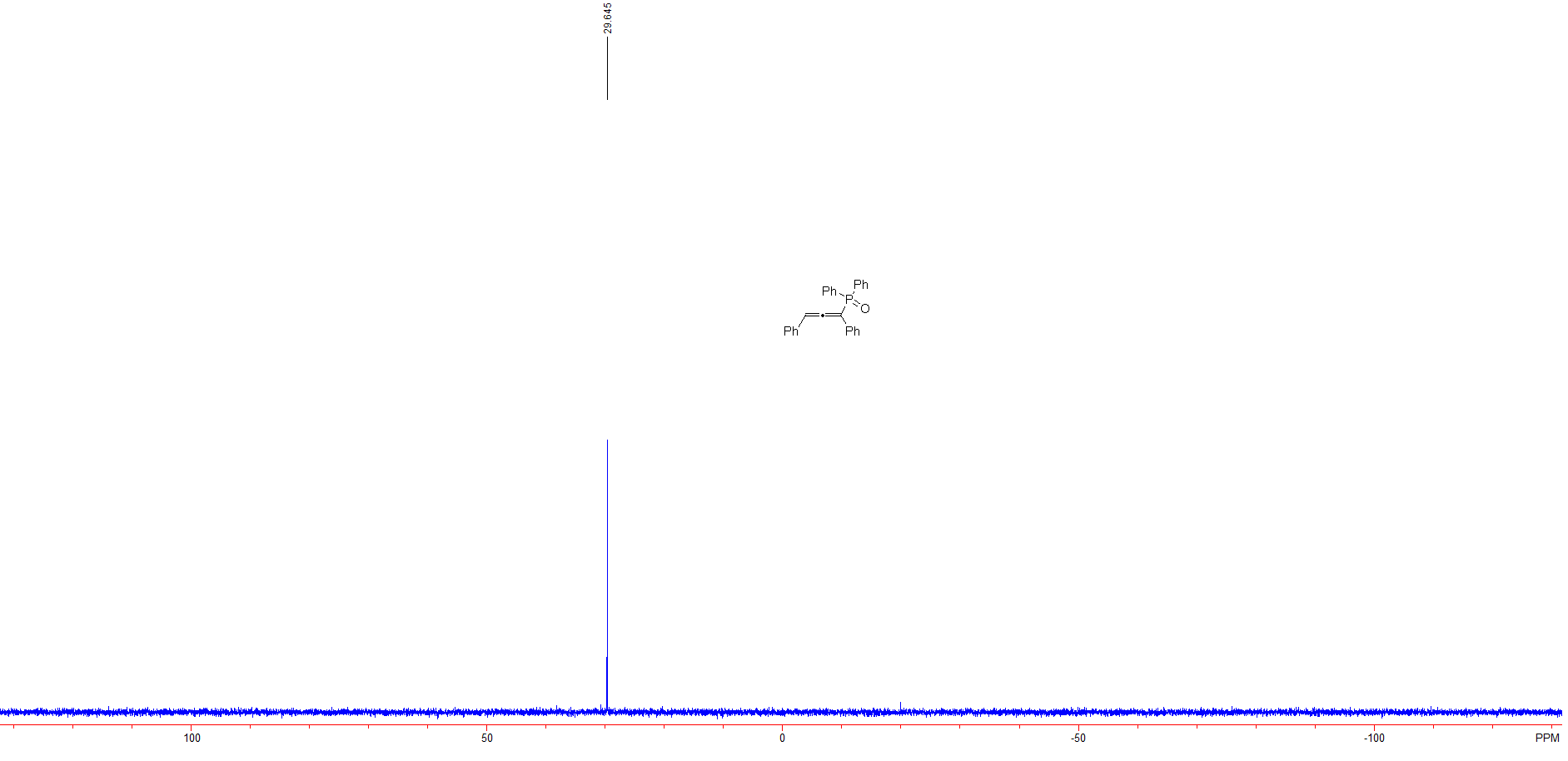
**Figure S 24:** 1H NMR spectra of (1-cyclohexylidene-3,3-dimethylbut-1-en-2-yl)diphenylphosphine oxide (**3m**)



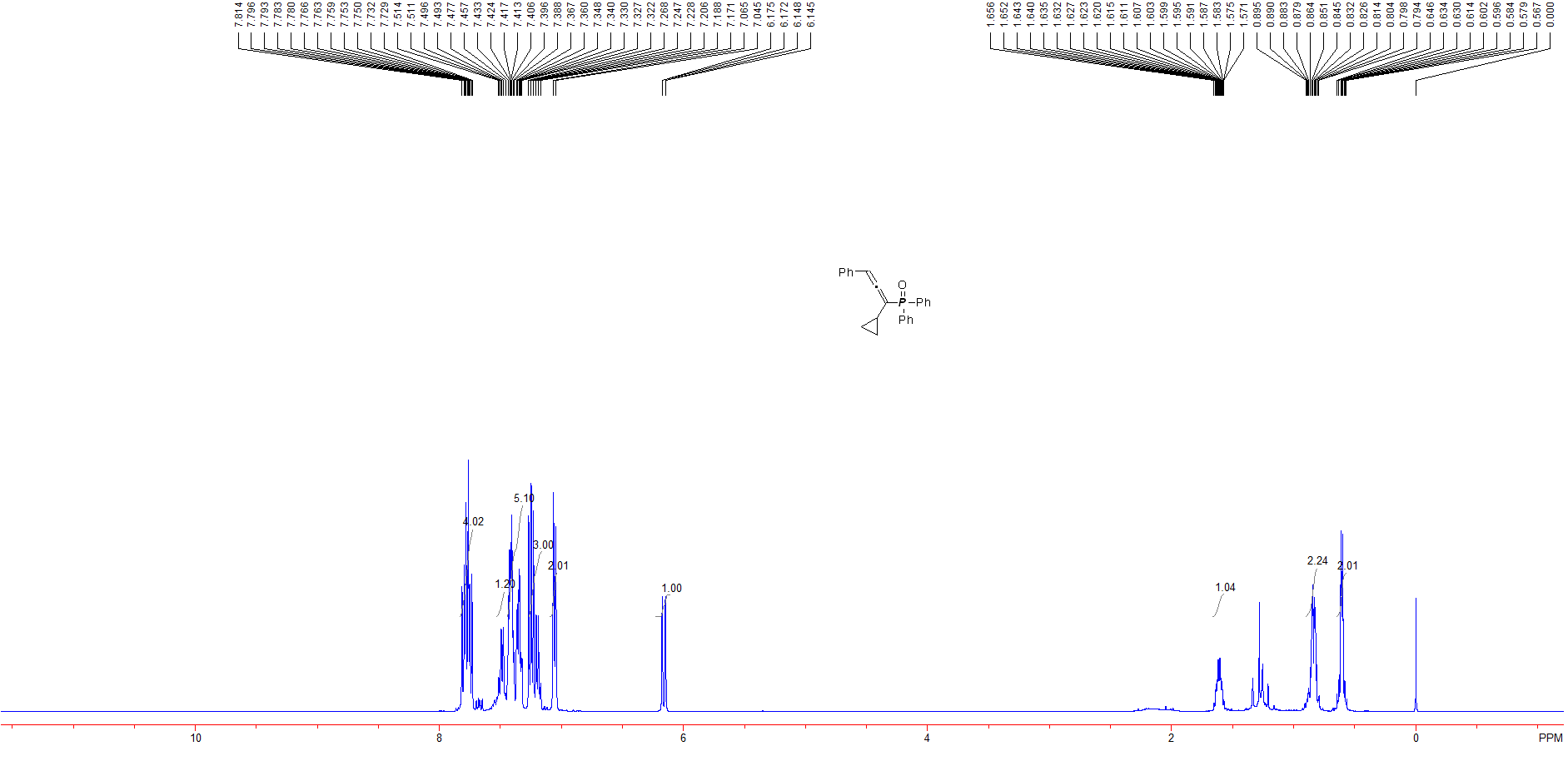
**Figure S 25:** 31P NMR spectra of (1-cyclohexylidene-3,3-dimethylbut-1-en-2-yl)diphenylphosphine oxide (**3m**)



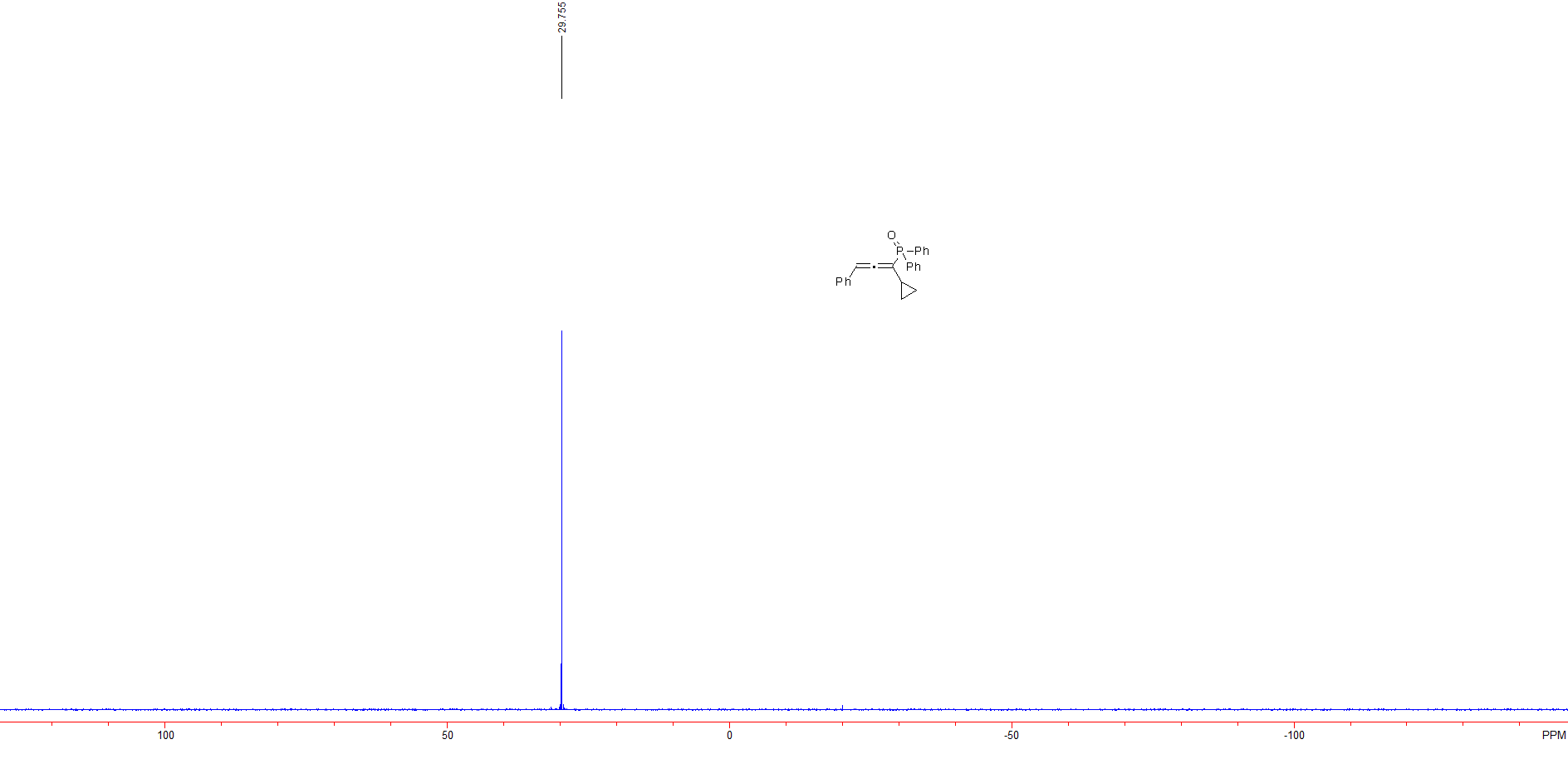
**Figure S 26:** 1H NMR spectra of (1,3-diphenylpropa-1,2-dien-1-yl)diphenylphosphine oxide (**3n**)



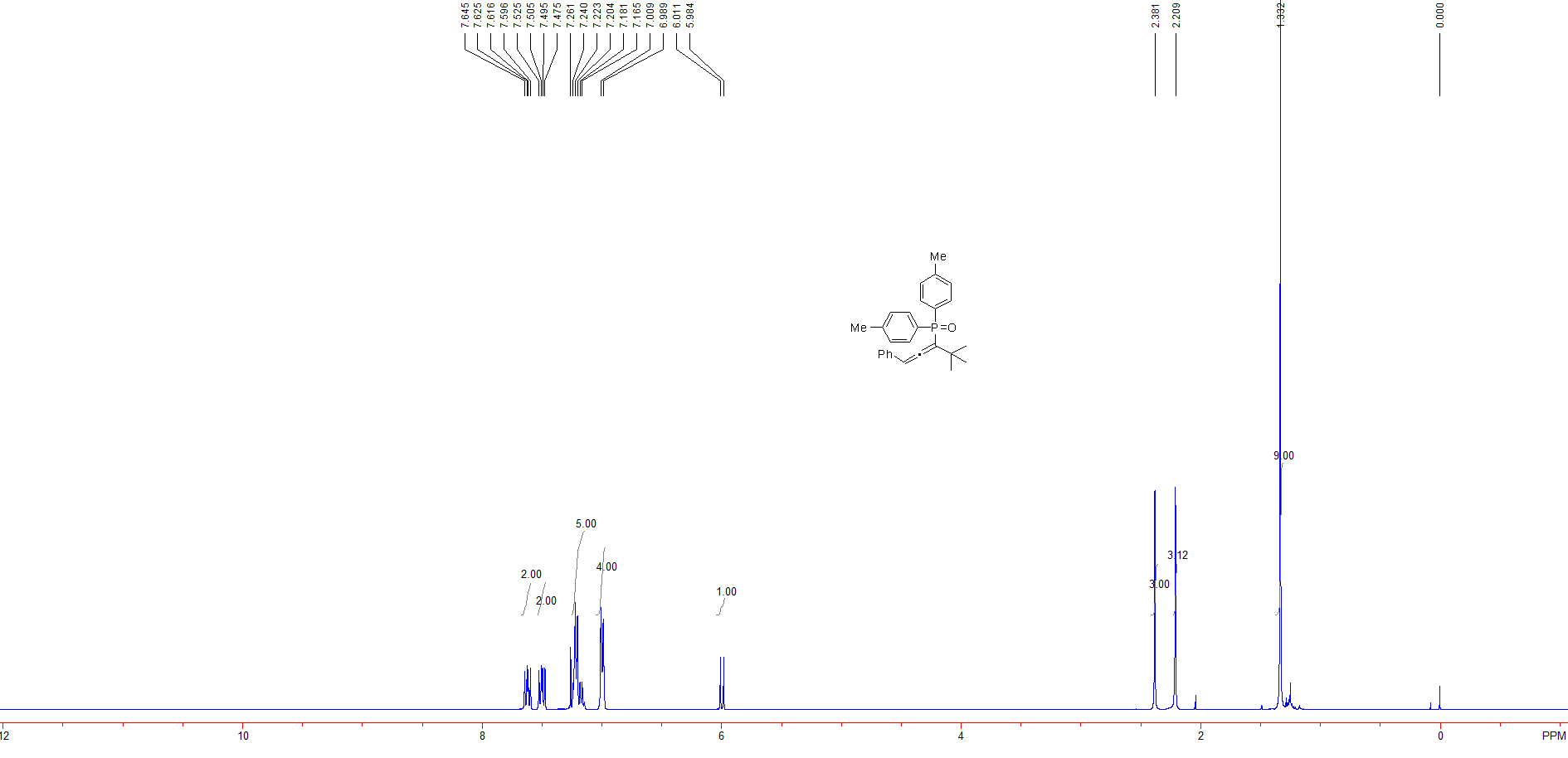
**Figure S 27:** 31P NMR spectra of (1,3-diphenylpropa-1,2-dien-1-yl)diphenylphosphine oxide (**3n**)



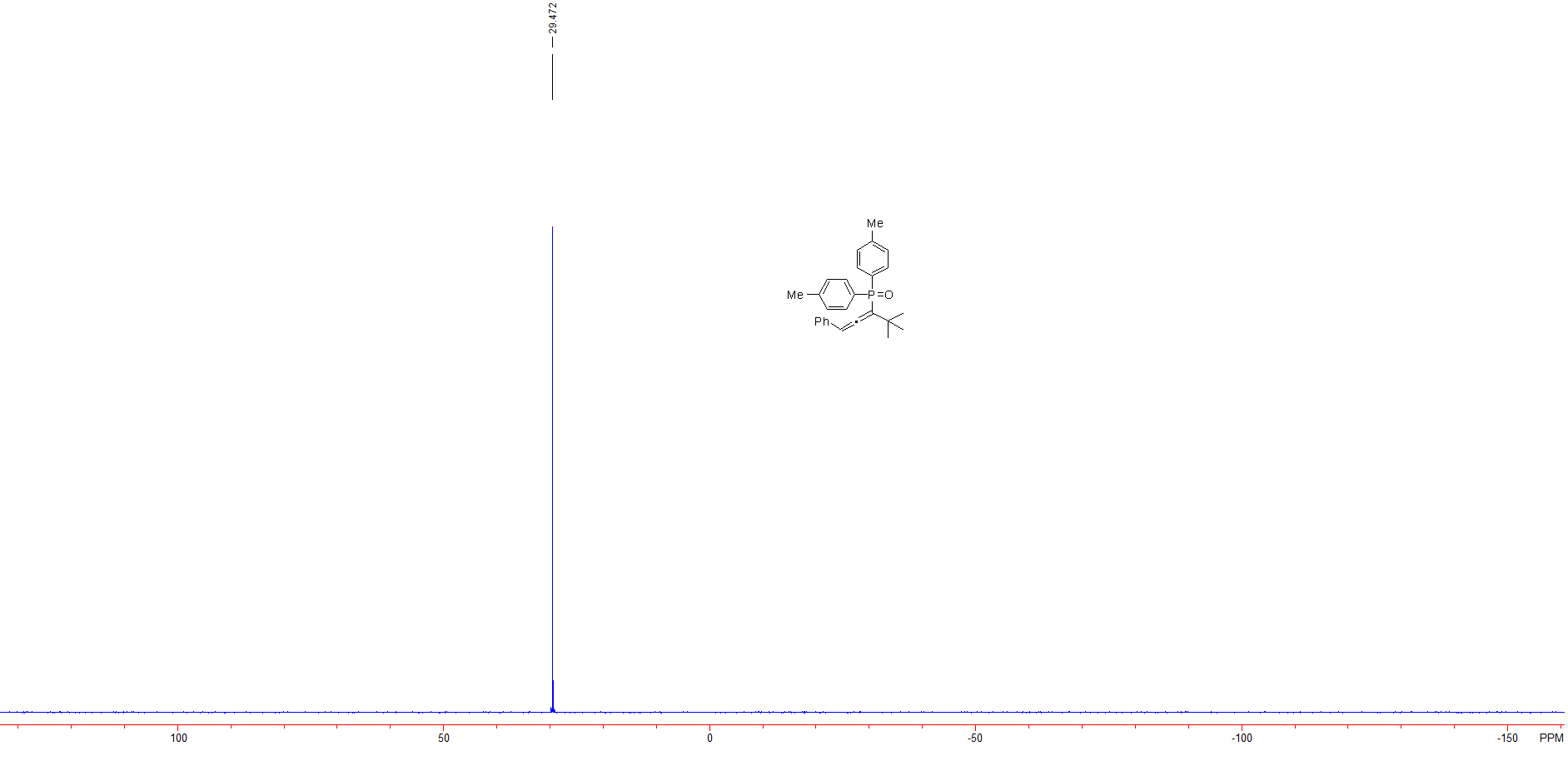
**Figure S 28:** 1H NMR spectra of (1-cyclopropyl-3-phenylpropa-1,2-dien-1-yl)diphenylphosphine oxide (**3o**)



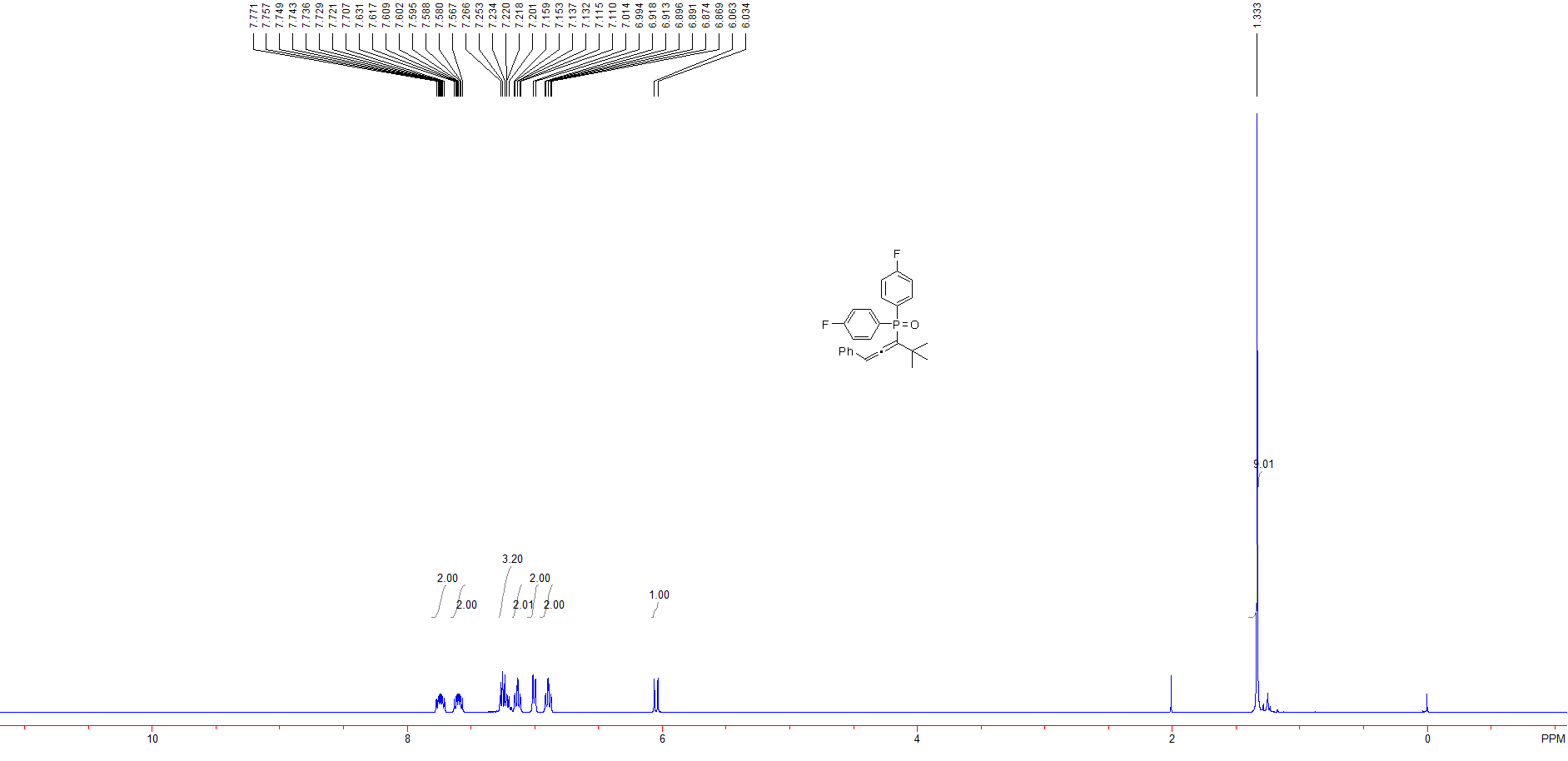
**Figure S 29:** 31P NMR spectra of (1-cyclopropyl-3-phenylpropa-1,2-dien-1-yl)diphenylphosphine oxide (**3o**)



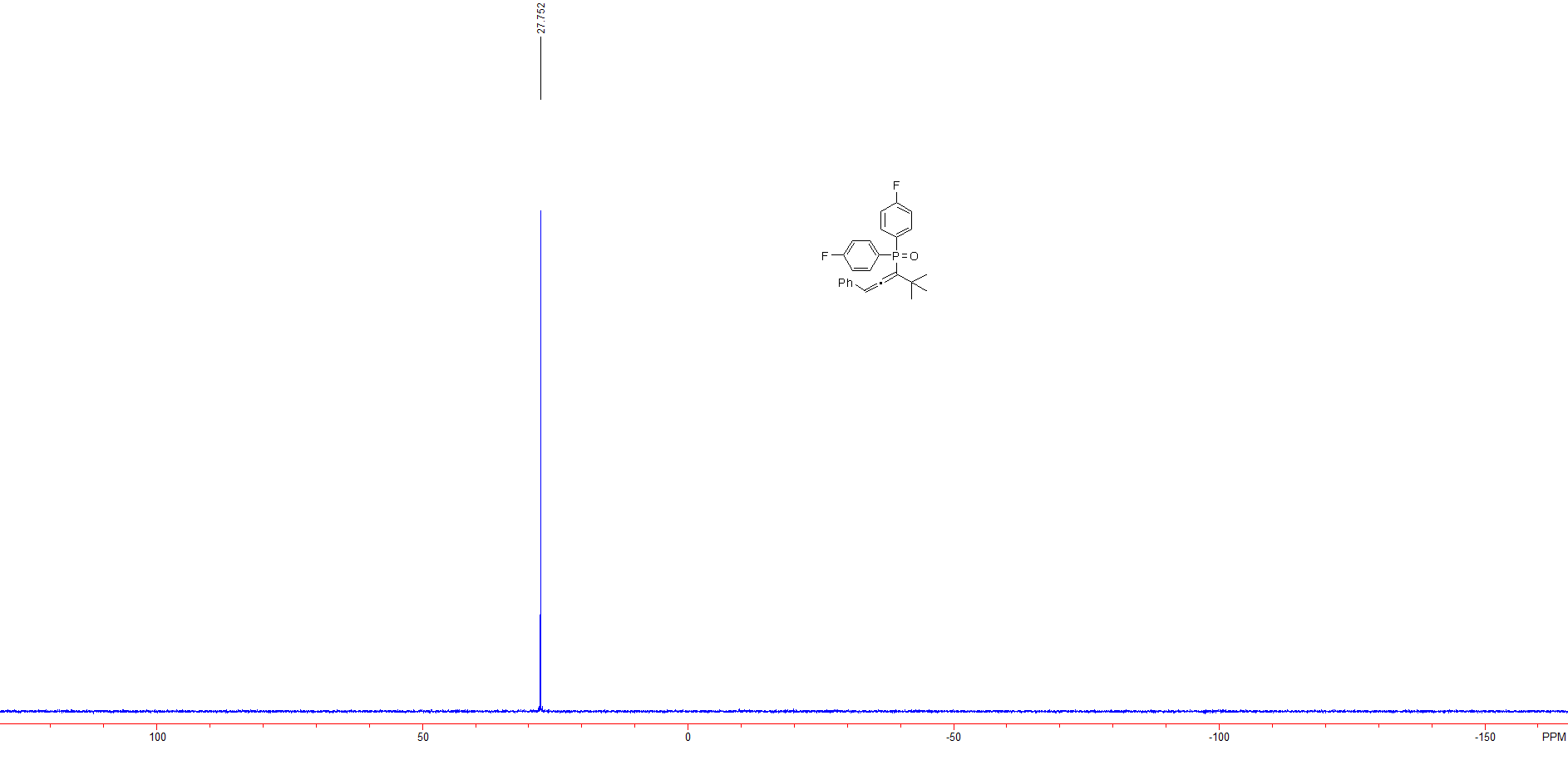
**Figure S 30:** 1H NMR spectra of (4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)di-p-tolylphosphine oxide (**3p**)



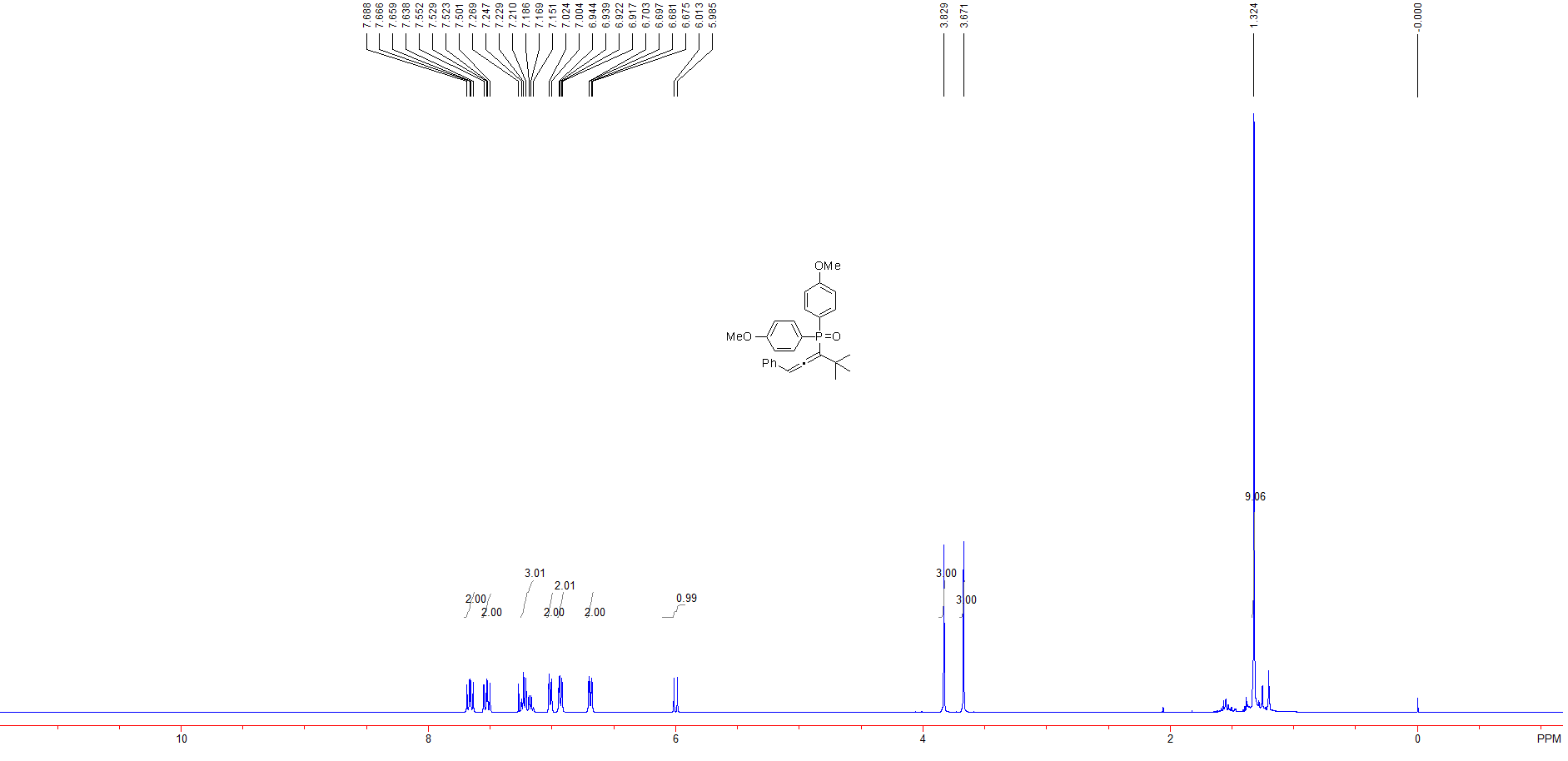
**Figure S 31:** 31P NMR spectra of (4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)di-p-tolylphosphine oxide (**3p**)



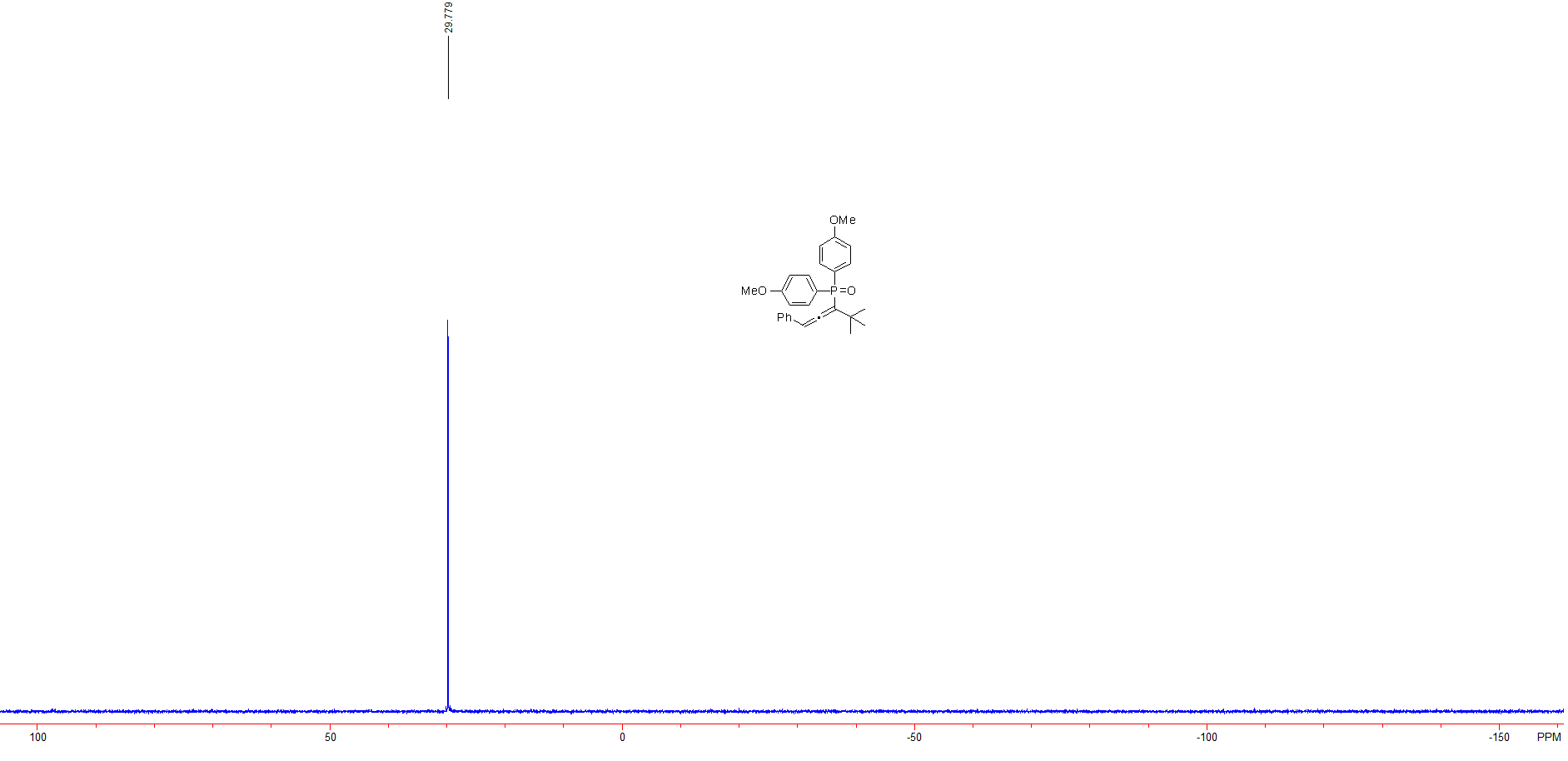
**Figure S 32:** 1H NMR spectra of (4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)bis(4-fluorophenyl)phosphine oxide (**3q**)



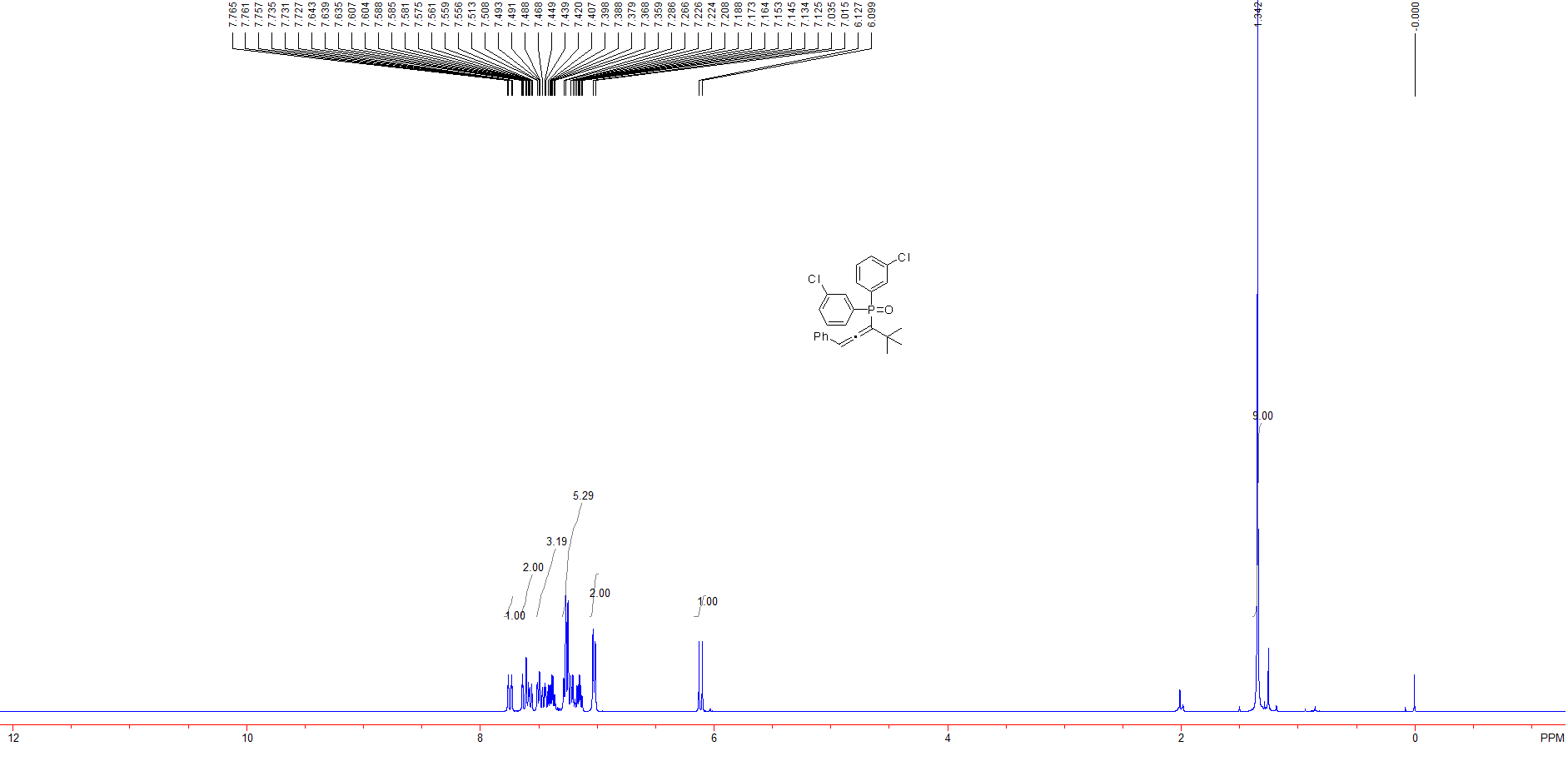
**Figure S 33:** 31P NMR spectra of (4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)bis(4-fluorophenyl)phosphine oxide (**3q**)



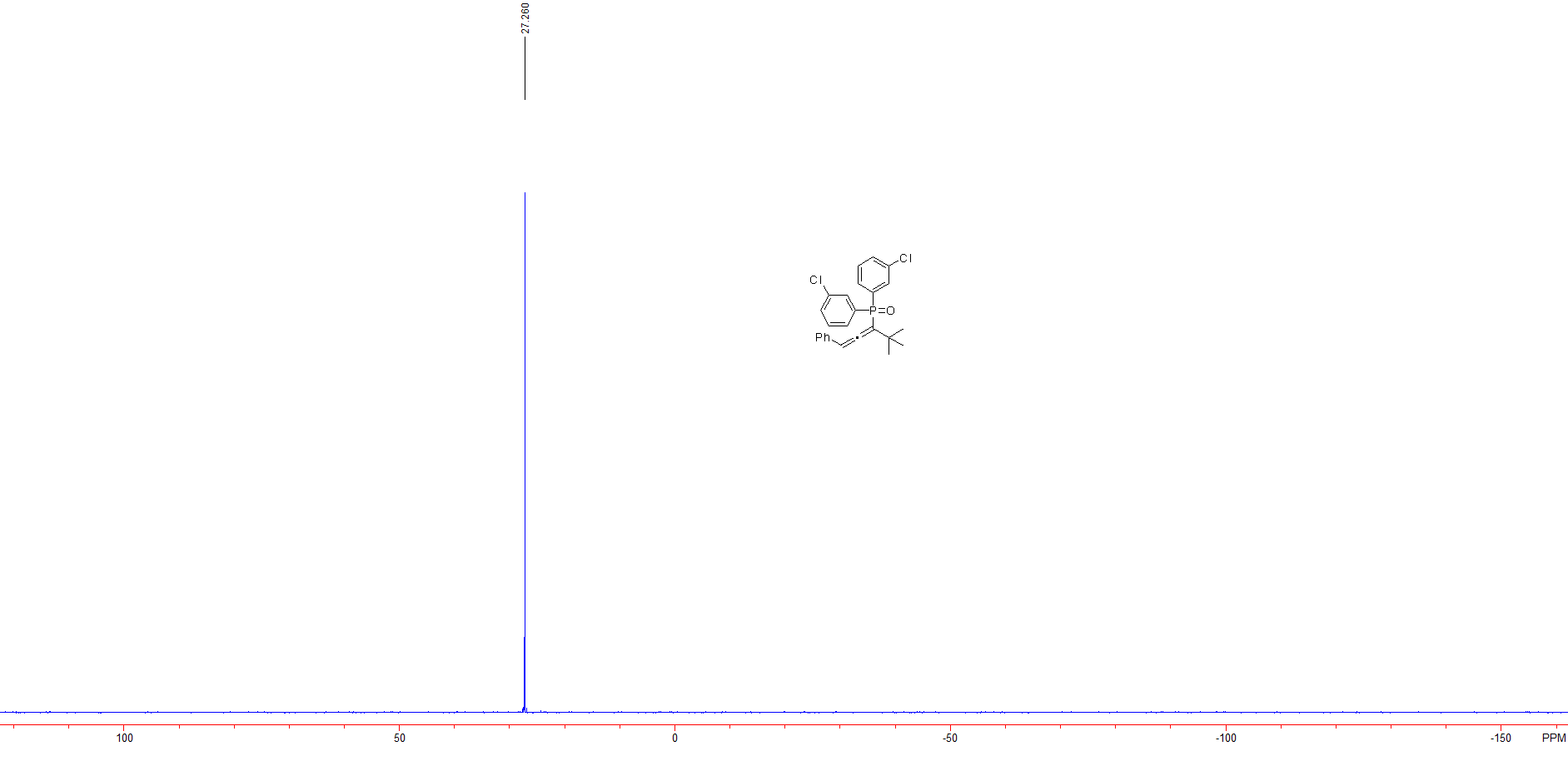
**Figure S 34:** 1H NMR spectra of (4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)bis(4-methoxyphenyl)phosphine oxide (**3r**)



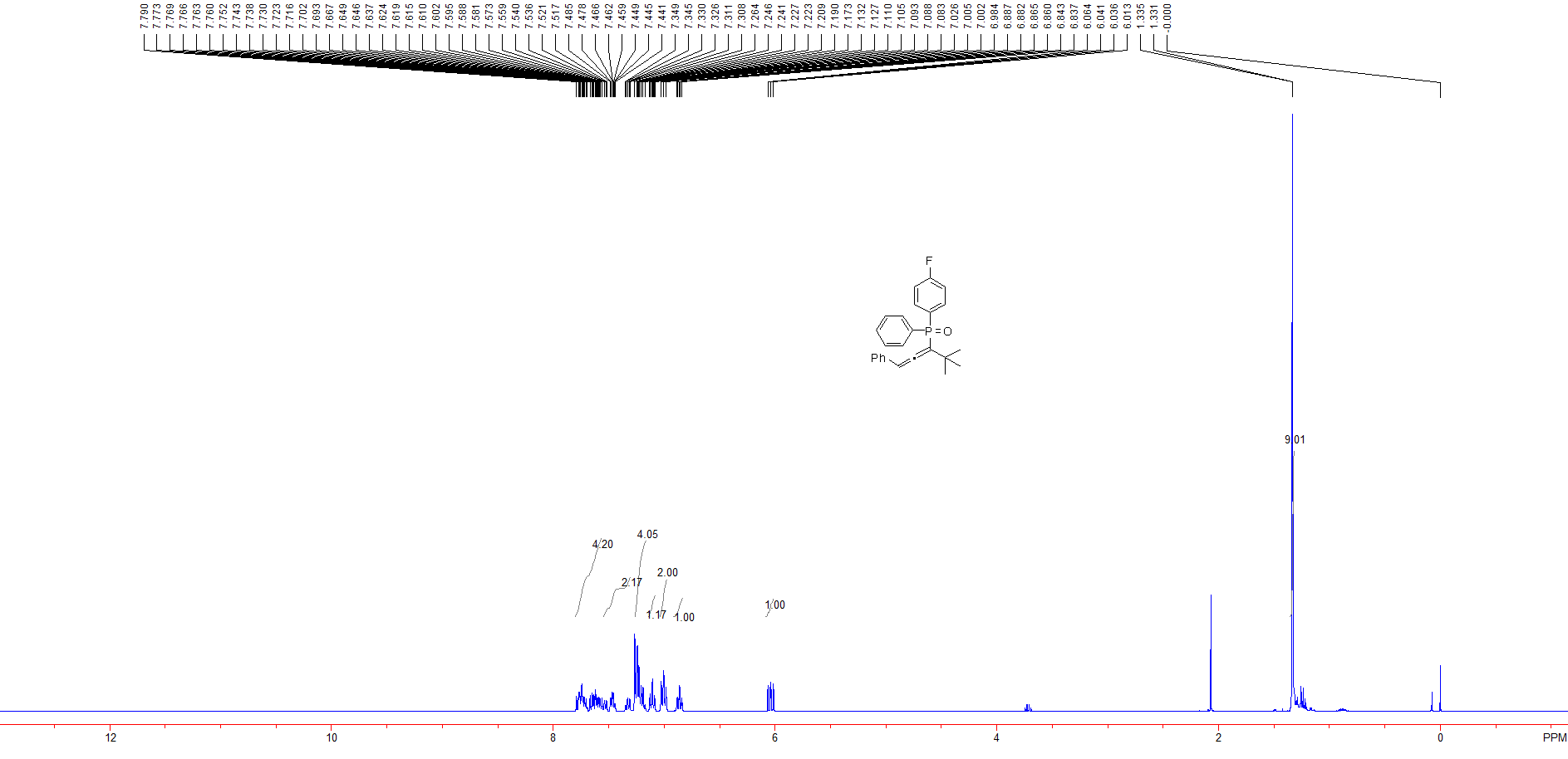
**Figure S 35:** 31P NMR spectra of (4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)bis(4-methoxyphenyl)phosphine oxide (**3r**)



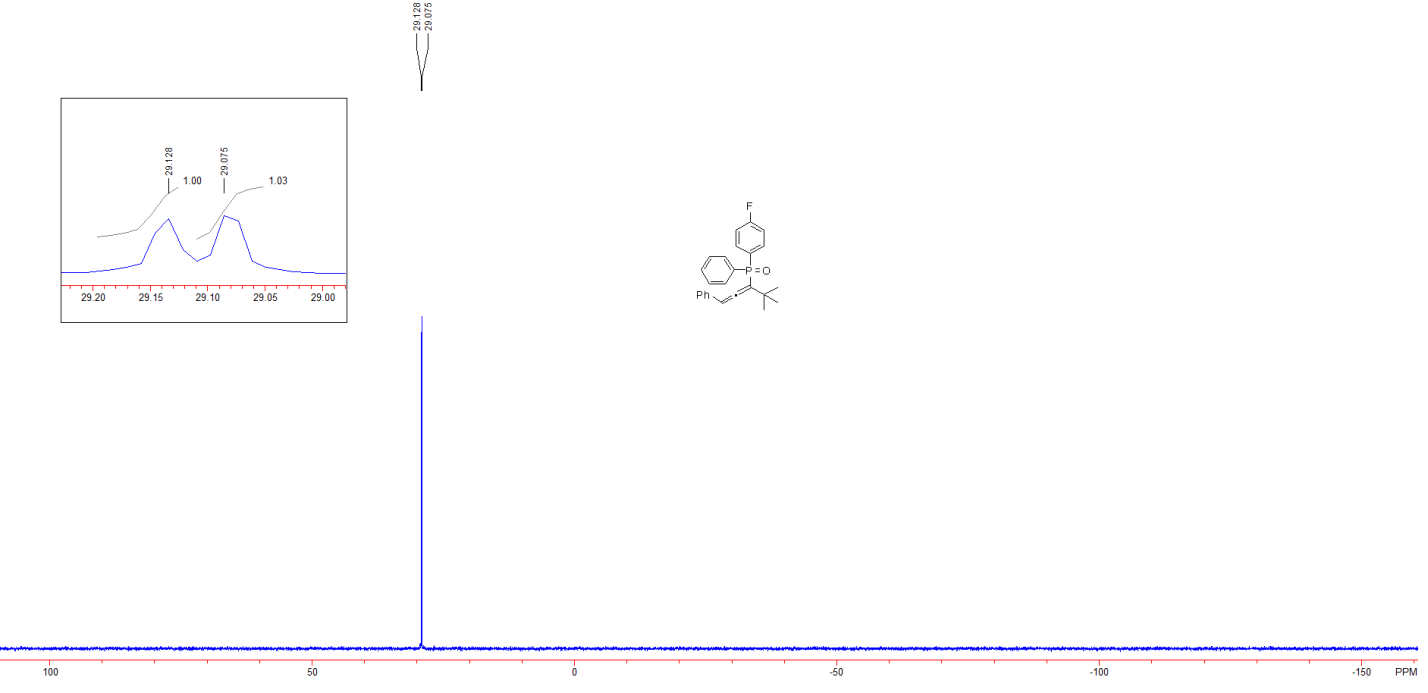
**Figure S 36:** 1H NMR spectra of bis(3-chlorophenyl)(4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)phosphine oxide (**3s**)



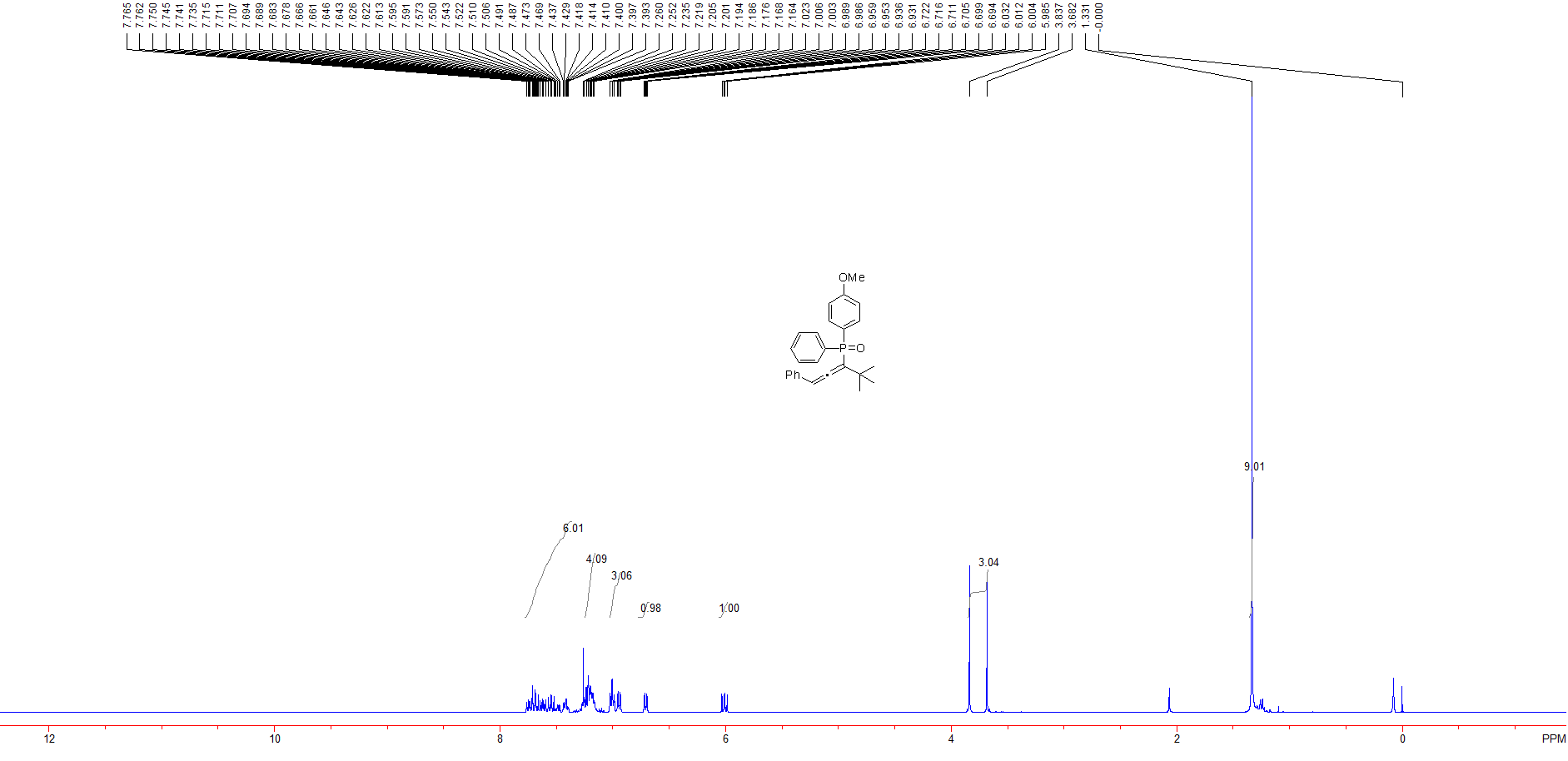
**Figure S 37:** 31P NMR spectra of bis(3-chlorophenyl)(4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)phosphine oxide (**3s**)

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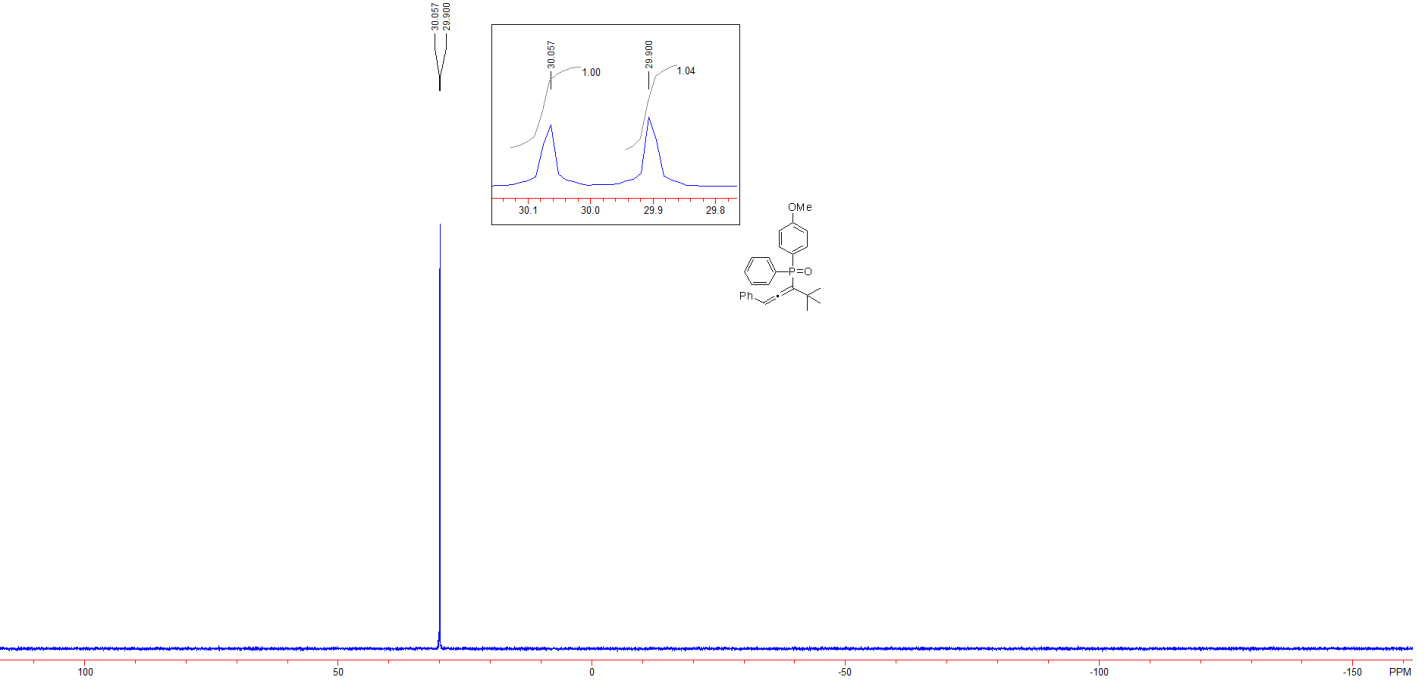
**Figure S 38:** 1H NMR spectra of (4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)(4-fluorophenyl)(phenyl) phosphine oxide (**3t**)



**Figure S 39:** 31P NMR spectra of (4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)(4-fluorophenyl)(phenyl) phosphine oxide (**3t**)

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**Figure S 40:** 1H NMR spectra of (4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)(4-methoxyphenyl)(phenyl) phosphine oxide (**3u**)



**Figure S 41:** 31P NMR spectra of (4,4-dimethyl-1-phenylpenta-1,2-dien-3-yl)(4-methoxyphenyl)(phenyl) phosphine oxide (**3u**)