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# Synthesis of new triphenylphosphines with pending ethynyl substituents

Guillaume Grelaud, Gilles Argouarch, Frédéric Paul *

*UMR CNRS 6226 Sciences Chimiques de Rennes, Université de Rennes 1, Campus de Beaulieu, 35042 Rennes Cedex, France*

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ABSTRACT

The straightforward isolation and characterization of new triphenylphosphines possessing a pendent ethynyl substituent on one or several peripheral aryl ring(s) are reported. The synthesis of this family of compounds is achieved by retro-Favorsky reactions from the corresponding propargylic alcohol derivatives, themselves obtained following a classic Sonogashira-type coupling between the *ad hoc* bromophenyl phosphines and 2-methylbut-3-yn-2-ol.



Over the last fifty years, the constant research for improving the yields of various catalytic transformations has fostered the search of more and more sophisticated ligands and led to the development of a great number of new phosphines, among which are a large number of variously functionalized triarylphosphines.[1] However, in spite of these impressive synthetic achievements, only a handful of reports was concerned with the synthesis of ethynylated triarylphosphines.[2–4] In our mind, these ligands deserve a particular interest which largely exceeds the field of catalysis.[2,4–6] First, the very diverse and specific reactions of the ethynyl substituent(s) allow one to undertake a wide range of organic or inorganic structural modifications on these peculiar triarylphosphines.[7] Then, by virtue of its unsaturated and rigid core, the alkyne spacer permits a good electronic communication between the phosphorus atom and any appended fragment, while controlling their relative spatial orientation.[8] Thus, ethynylated triarylphosphines such as **1–6** (Scheme 1) constitute strategic precursors en route toward new functional ligands.

To the best of our knowledge, only **1** has been reported so far among them (Scheme 2).[2,9,10] Its synthesis has been achieved by deprotecting the trimethylsilyl precursor **7**; the latter being obtained either (i) by the reaction of the diphenylphosphide anion and ((4-bromophenyl)ethynyl)trimethylsilane (**8**)[2] or (ii) by the reaction of 4-(trimethylsilylethynyl)phenylate anion and chlorodiphenylphosphine.[9] Low yields are reported for the first route, making the second one more attractive. However, in our hands,[11] using potassium carbonate instead of PPS-supported carbonate for the deprotection, this route proved not so effective, since large amounts of phosphine oxide were formed each time, resulting in overall low yields in the desired phosphine **1**. This led us to develop another general synthetic access to this known compound and its new analogues **2–6** starting from the corresponding brominated phosphines.

Actually, the desired alkynylated targets can be accessed by catalytic cross-coupling reactions from the corresponding brominated phosphines (Scheme 3). These precursors are available in good yields from commercial dibromoarenes using lithium halogen exchange with butyl lithium, followed by electrophilic trapping with the corresponding chlorophosphines.[12–15] By this means, 4- and 3-bromophenylene phosphine derivatives **1a–6a** were isolated in one step on a multi-gram scale. Reacting these known phosphines with dimethylethynylcarbinol under typical Sonogashira conditions produces the corresponding propargylic alcohol derivatives **1b–6b** in good yields after purification by column chromatography (Table 1).[16–18] In spite of the excess brominated phosphine used as the reactant, the coupling reaction took place within days. Thus, the excess phosphine present in the medium as the reactant or product does not poison the active species of the transformation by favoring the formation of coordinatively saturated species.[1]

An interesting feature of **1b–6b** is that their very polar nature allows an easy separation of the final compounds from the unreacted starting products and also from the pervasive phosphine oxide formed as side-products during work-up of the Sonogashira coupling reaction. These new products are obtained as yellow gums or white solids. They were characterized by HRMS, IR, and NMR and also by elemental analyses in several cases (see Supplementary data). $^{31}$P NMR constitutes a convenient probe to check the purity of the isolated product. As expected for these triarylphosphines, a unique singlet between −4 and −5 ppm was

* Corresponding author. Tel./fax: +33 02 23 23 59 62.
*E-mail address:* frederic.paul@univ-rennes1.fr (F. Paul).

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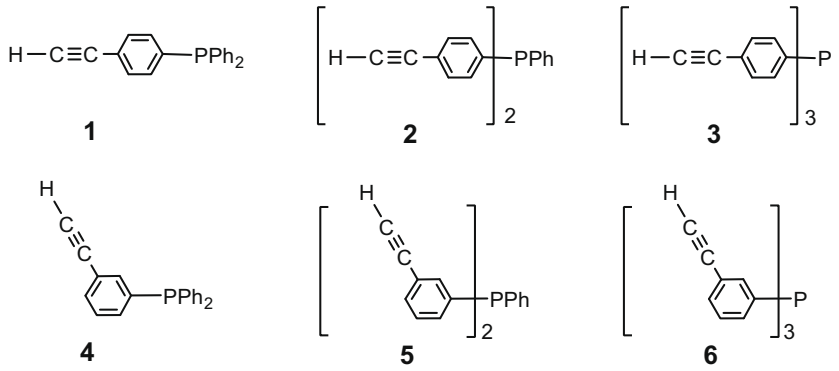
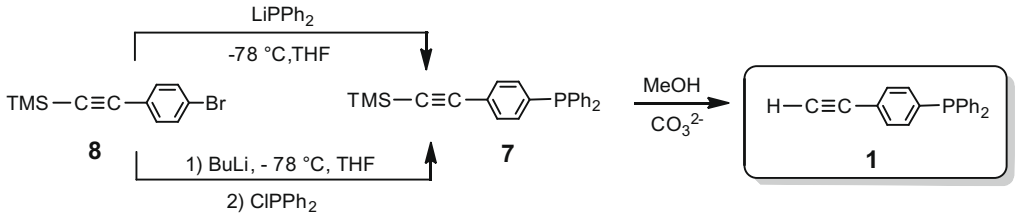


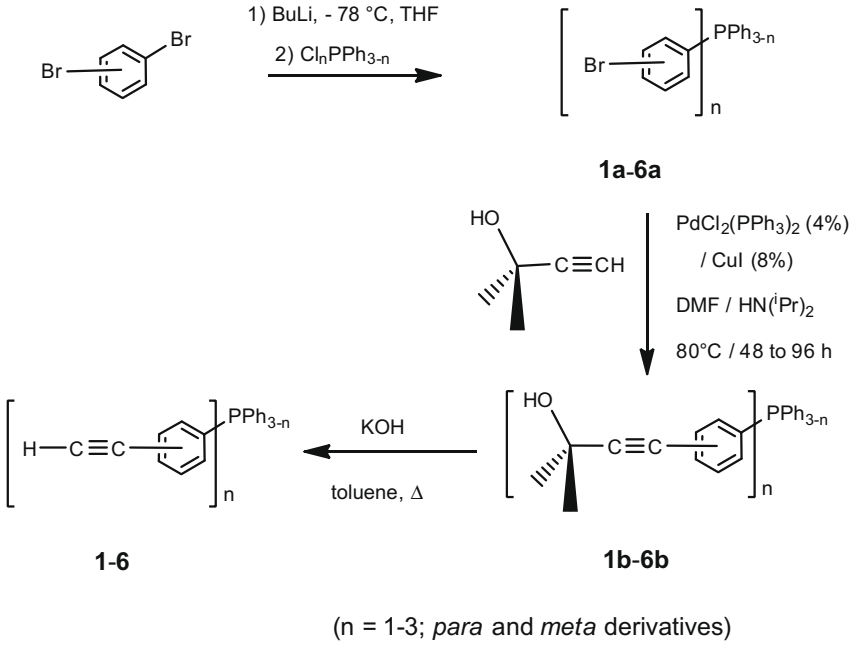

**Scheme 1.** Selected ethynylated triphenylphosphine derivatives.




**Scheme 2.** Previously reported syntheses of **1**.

detected each time, evidencing the absence of any trace of the corresponding phosphine oxides in the isolated products.[3,5] The presence of the dimethyl propargylic substituents in **1b–6b** was confirmed by a diagnostic triple bond stretching vibration around 2100 $cm^{-1}$ and a large $\nu_{OH}$ stretching vibration between 3200 and 3400 $cm^{-1}$.

3-Propargyl alcohol substituents are well known precursors of terminal alkynes.[16] Accordingly, **1b–6b** could be converted into the desired phosphines using a base-catalyzed retro-Favorsky reaction. Thus, when heated in toluene in the presence of excess potassium hydroxide, these compounds produced the desired corresponding ethynyl-substituted triarylphosphines **1–6**. The latter could be isolated pure as yellow oils in excellent yields after filtration on silica (Table 2) and were characterized by IR and NMR. The new phosphines **2–6** were also characterized by HRMS. The spectroscopic signatures of **1–6** are diagnostic of their structures. They exhibit a singlet near −4 ppm in $^{31}P$ NMR for the central phosphorus atom and the presence of the terminal triple bond is




**Scheme 3.** New synthetic route toward **1–6**.

**Table 1**
Yields and selected spectral signatures of the propargylic triarylphosphines **1b–6b**

| Product | Yield (%) | $\nu_{OH}$[a] ($cm^{-1}$) | $\nu_{C\equiv C}$[a] ($cm^{-1}$) | $^{31}P\{^1H\}$NMR[b] $\delta_P$ (ppm) | $^{13}C\{^1H\}$ NMR $\delta_{C\equiv C}$ (ppm) | $^1H$ NMR $\delta_{OH}$ (ppm) |
|---|---|---|---|---|---|---|
| **1b** (*para*; $n = 1$) | 72 | 3349 (vs) | 2238 (w) | −4.2 | 95.8 (s), 82.3 (s) | 2.53 |
| **2b** (*para*; $n = 2$) | 68 | 3378 (vs) | 2229 (w) | −4.4 | 95.7 (s), 82.2 (s) | 3.11 |
| **3b** (*para*; $n = 3$) | 63 | 3329 (vs) | 2234 (w) | −4.9[c] | 98.5 (s), 80.8 (s)[d] | 4.53[c] |
| **4b** (*meta*; $n = 1$) | 71 | 3354 (vs) | 2247 (w) | −4.2 | 94.9 (s), 82.3 (s) | 2.09 |
| **5b** (*meta*; $n = 2$) | 75 | 3322 (vs) | 2243 (w) | −4.5 | 95.3 (s), 82.1 (s) | 3.55 |
| **6b** (*meta*; $n = 3$) | 68 | 3237 (vs) | 2291 (w) | −4.6[c] | 98.0 (s), 80.6 (s)[d] | 4.56[c] |

[a] Neat in KBr (±2 $cm^{-1}$).
[b] Unless precised, all NMR were recorded in $CDCl_3$.
[c] In acetone-$d_6$.
[d] In DMSO-$d_6$.

**Table 2**
Yields and selected spectral signatures of the ethynylated triarylphosphines **1–6**

| Product | Yield (%) | $\nu_{\equiv CH}$[a] ($cm^{-1}$) | $\nu_{C\equiv C}$[a] ($cm^{-1}$) | $^{31}P\{^1H\}$ NMR[b] $\delta_P$ (ppm) | $^{13}C\{^1H\}$ NMR $\delta_{C\equiv C}$ (ppm) | $^1H$ NMR $\delta_{\equiv CH}$ (ppm) |
|---|---|---|---|---|---|---|
| **1** (*para*; $n = 1$) | 94 | 3286 (s) | 2106 (w) | −4.1 | 83.9 (s), 78.9 (s) | 3.15 |
| **2** (*para*; $n = 2$) | 91 | 3298 (s) | 2107 (w) | −4.1 | 83.8 (s), 79.2 (s) | 3.16 |
| **3** (*para*; $n = 3$) | 90 | 3288 (w) | 2107 (w) | −4.2 | 83.9 (s), 78.7 (s) | 3.18 |
| **4** (*meta*; $n = 1$) | 90 | 3288 (s) | 2109 (w) | −4.3 | 83.8 (s), 79.1 (s) | 3.08 |
| **5** (*meta*; $n = 2$) | 80 | 3288 (s) | 2109 (w) | −4.3 | 83.7 (s), 79.1 (s) | 3.13 |
| **6** (*meta*; $n = 3$) | 81 | 2291 (w) | 2291 (w) | −4.6 | 83.6 (s), 78.6 (s) | 3.12 |

[a] Neat in KBr (±2 $cm^{-1}$).
[b] All NMR were recorded in $CDCl_3$.

evidenced by characteristic $^{13}C/^1H$ NMR shifts and IR stretches. Notably, **1–6** are more reactive substances than their propargylic alcohol precursors **1b–6b**. They slowly decompose and turn dark upon standing at 25 °C under air and should therefore be stored under inert atmospheres at low temperature or used as soon as possible, once prepared.

In conclusion, we have reported here a new and general synthetic route toward the ethynylated triphenylphosphine derivatives **1–6** which allows obtaining these ligands in fair yields (Table 2) after three steps from commercially available starting materials. In contrast to the previous syntheses of **1** and related compounds, the ethynyl fragment is presently introduced after performing the phosphination reaction. This synthetic approach, while limiting the formation of phosphine oxides or other undesired side-products, allows a simple purification of the intermediates after each step. Regarding the known compound **1**, the present route stands the comparison with the previously reported syntheses based on the trimethylsilylalkynyl precursor **7**, without the need for any solid state reactant. Considering the large array of selective transformations existing for terminal alkynyl groups, **1–6** open a synthetic route toward various classes of new functional phosphines for catalysis or supramolecular chemistry.

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## Supplementary data

Supplementary data (experimental details for the synthesis and characterization data for various compounds) associated with this article can be found, in the online version, at doi:10.1016/j.tetlet.2010.05.055.

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