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Palladium catalyzed co-trimerization of benzyne with alkynes. A facile method for the synthesis of phenanthrene derivatives

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Abstract

A facile method for the synthesis of phenanthrene derivatives by the palladium catalyzed co-trimerization of benzyne with alkynes is described. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: palladium catalysts; co-trimerization; benzyne; phenanthrene.

Transition metal catalyzed synthetic transformations have attracted the attention of synthetic organic chemists over the last 10 years, since they offer promising and superior alternatives to most of the classical methods which often suffer from lack of regio-, chemo-, and stereoselectivities, and of tolerance of functional groups. Among these, the cyclotrimerization of alkynes to the corresponding aromatic compounds has been the subject of extensive investigations.[1] Our own work in this area has revealed the fascinating role of palladium in carrying out selective transformations.[2] We have reported effective methods for the preparation of substituted benzene derivatives via the palladium catalyzed enyne–diyne cross-benzannulation reaction[3] and also the [4+2] cyclodimerization of conjugated enynes.[4] As part of this programme, we undertook an investigation on the co-trimerization of benzyne with alkynes. Arynes are known to undergo cyclotrimerization under palladium catalysis leading to the formation of triphenylenes.[5] Our studies were initiated with the reaction of **1** and **2a** in the presence of a palladium acetate/(o-tol)$_3$P catalytic system at 60°C in acetonitrile (Scheme 1). The reaction proceeded smoothly, affording the phenanthrene derivative **3a** in 63% yield. The results obtained with different alkynes are summarized in Table 1.

Since completion of this work, an article by Pena et al.[6] has appeared which describes the synthesis of phenanthrenes and naphthalenes by co-cyclization of arynes with alkynes. According to this report, electron deficient alkynes, such as hexafluoro-2-butyne and DMAD, gave phenanthrene derivatives in the presence of Pd(Ph$_3$P)$_4$, while with Pd$_2$(dba)$_3$, they afforded naphthalene derivatives in good yields. It is interesting to note that with other alkynes studied, they did not observe any selectivity in the formation of phenanthrenes and naphthalenes. Phenanthrene derivatives were obtained, albeit in low yields, in the

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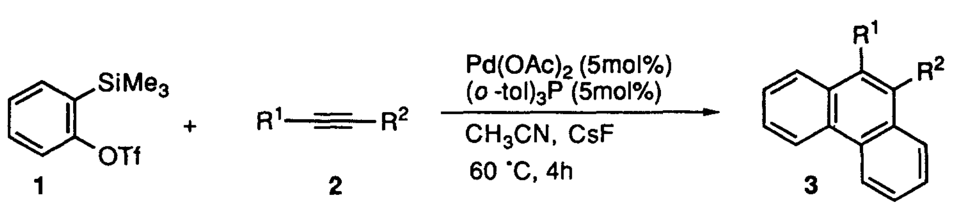

Scheme 1.

Table 1
Co-trimerization of benzyne with alkynes

Entry	Alkyne 2	R^1	R^2	Product 3 (% yield)[a, b]
1	**2a**	n-Pr	n-Pr	**3a**[c] (63)
2	**2b**	n-pentyl	n-pentyl	**3b**[c] (67)
3	**2c**	CH_2OMe	CH_2OMe	**3c**[c] (59)
4	**2d**	Ph	CH_3	**3d** (67)
5	**2e**	Ph	CH_2CH_3	**3e** (63)
6	**2f**	Ph	$COCH_3$	**3f** (76)

[a] Isolated yield. [b] All compounds gave satisfactory spectral data.
[c] Trace amount of triphenylene were also formed

case of electron rich alkynes. It is noteworthy that our method, utilizing the $Pd(OAc)_2/(o\text{-tol})_3P$ catalyst system, afforded the phenanthrene derivatives exclusively in good yields regardless of the electronic nature of the alkynes.

General experimental procedure. The benzyne precursor **1** (0.4 mmol) was added to a suspension of anhydrous CsF (0.8 mmol), $Pd(OAc)_2$ (5 mol%) and $(o\text{-tol})_3P$ (5 mol%) in CH_3CN (2 mL). Alkynes (0.6 mmol) were then added and the mixture was stirred at 60°C for 4 h. When the reaction was complete (monitored by TLC and GC), the solvent was evaporated and the residue was subjected to silica gel column chromatography to isolate the phenanthrene derivatives.

In conclusion, we have developed an efficient method for the synthesis of phenanthrene derivatives by the palladium catalyzed co-trimerization of benzyne with alkynes. The phenanthrene skeleton is found in a number of biologically active natural products,[7] but many of the reported methods[8] suffer from lack of selectivity, poor yields and harsh conditions. In view of the above, the present method is a promising and presumably general method for the synthesis of phenanthrene derivatives. Further work along this line is in progress and will be published shortly.

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