



Efficient copper(I)-catalyzed coupling of secondary phosphine oxides with aryl halides



Marek Stankevič*, Adam Włodarczyk

Department of Organic Chemistry, Faculty of Chemistry, Marie Curie-Skłodowska University, Gliniana 33, 20-614 Lublin, Poland

ARTICLE INFO

Article history:

Received 3 July 2012

Received in revised form 3 October 2012

Accepted 22 October 2012

Available online 30 October 2012

Keywords:

Coupling reaction

Copper(I) iodide

Secondary phosphine oxides

Tertiary phosphine oxides

Diphosphine dioxides

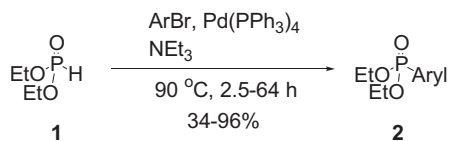
ABSTRACT

A catalytic system has been developed for the efficient synthesis of tertiary arylphosphine oxides by coupling of readily available secondary phosphine oxides with aryl bromides or iodides in the presence of copper(I) iodide as a catalyst and (*S*)- α -phenylethylamine as a ligand. The system exhibits high activity in the coupling of secondary diaryl-, alkylaryl- and dialkylphosphine oxides.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

The palladium-catalyzed coupling of secondary phosphites with sp^2 carbon electrophiles described by Hirao and co-workers in 1981¹ provided a new and powerful method for the synthesis of aryl or alkenylphosphorus compounds from readily accessible $>P(X)H$ -type compounds (Scheme 1).

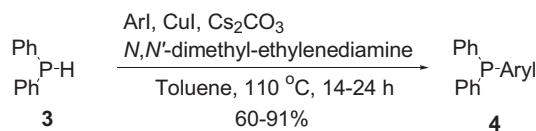


Aryl = Ph, *p*-Tol, *o*-Tol, *p*-Cl-C₆H₄, *o*-An, *p*-NO₂-C₆H₄, *p*-Ac-C₆H₄, *p*-AcNH-C₆H₄, *p*-CN-C₆H₄, *p*-Br-C₆H₄, *o*-Br-C₆H₄, 1-naphthyl, 3-pyridyl

Scheme 1. Palladium-catalyzed coupling of diethyl phosphite with aryl bromides.

Since then, palladium catalysts have become standard tools for the coupling of other types of phosphorus nucleophiles, such as secondary phosphites,² *H*-phosphinates,³ secondary phosphine oxides,⁴ secondary phosphine-boranes,⁵ and secondary phosphines.⁶ The last of these can be regarded as direct precursors for tertiary arylphosphines, which are valuable ligands in transition

metal-catalyzed transformations. However, despite all of the advantages of palladium catalysts, their use in the cases above is prohibitively expensive because an effective Hirao coupling generally requires 5–10 mol % of catalyst. The solution to this problem could lie in the use of less expensive transition metals possessing similar activity profiles. A brief look at the literature suggests that nickel, which is especially suitable as a catalyst for the coupling of secondary phosphines,⁷ secondary phosphine-boranes,⁸ and secondary phosphine oxides,⁹ might be regarded as a viable palladium substitute. Another candidate is copper. This has been successfully applied in the coupling of secondary phosphites,¹⁰ *H*-phosphinates,¹¹ and also secondary phosphines, which appear to couple very efficiently in the presence of copper salts to yield the corresponding tertiary phosphines (Scheme 2).¹²



Aryl = 1-naphthyl, *o*-An, *o*-NH₂-C₆H₄, *o*-Br-C₆H₄, *o*-Ph-C₆H₄, 3-pyridyl

Scheme 2. Copper-catalyzed coupling of secondary phosphines.

In the case of palladium complexes, reports concerning the use of copper salts for the coupling of secondary phosphine oxides with aryl halides are rare. A few examples concerning the coupling of

* Corresponding author. E-mail address: marek.stankevic@poczta.umcs.lublin.pl (M. Stankevič).

diphenylphosphine oxide with simple haloarenes have been presented by Fu and co-workers,¹³ and the coupling of three electron-deficient secondary phosphine oxides with C-chiral 2-(*o*-bromoaryl)oxazolines has been given by Stolz and co-workers.¹⁴

2. Results and discussion

As part of a research project directed toward the functionalization of the aryl substituents of arylphosphine and arylphosphorus acid derivatives through Birch reduction,¹⁵ we were interested in the efficient synthesis of tertiary arylphosphine oxides. We were pleased to find that treatment of *o*-anisylphenylphosphine oxide with *m*-xylyl iodide in the presence of CuI, *rac*-1,2-diaminocyclohexane and K₂CO₃ afforded the corresponding triarylphosphine oxide in 94% yield.¹⁶ This suggested that copper(I) salts might serve as good substitutes for palladium in coupling reactions involving secondary phosphine oxides. With this encouraging result in hand, we performed an optimization of the reaction conditions using **5a** and *o*-iodotoluene as substrates (Table 1, Scheme 3).

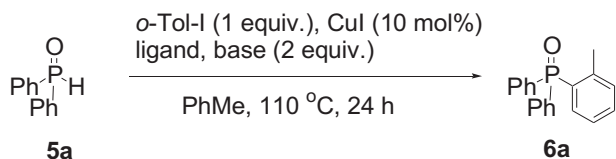
Table 1
Optimization of the reaction conditions in coupling of **5a** with *o*-iodotoluene

Nr	Ligand (mol %)	Base	Yield ^a of 6a %
1	L-Proline (20)	K ₂ CO ₃	44%
2	2-Picolinic acid (20)	K ₂ CO ₃	80%
3	(S)-α-Phenylethylamine (20)	K₂CO₃	87%
4	TMEDA (10)	K ₂ CO ₃	77%
5	DMEDA ^b (10)	K ₂ CO ₃	29%
6	Ethylenediamine (10)	K ₂ CO ₃	29%
7	2,2'-Bipyridine (10)	K ₂ CO ₃	63%
7	1,10-Phenanthroline (10)	K ₂ CO ₃	35%
8	PPh ₃ (20)	K ₂ CO ₃	71%
9	<i>n</i> Bu ₃ P (20)	K ₂ CO ₃	77%
10	<i>rac</i> -BINAP (10)	K ₂ CO ₃	74%
11	(S)- α -Phenylethylamine (20)	<i>t</i> -BuOK	30%
12	(S)- α -Phenylethylamine (20)	DABCO	20%
13	(S)- α -Phenylethylamine (20)	<i>i</i> Pr ₂ NEt	15%
14	(S)- α -Phenylethylamine (20)	Cs ₂ CO ₃	53%
15	L-Proline (20)	K ₂ CO ₃	44%

The entry in bold shows the best reaction conditions.

^a Yields after purification by column chromatography.

^b DMEDA—*N,N'*-dimethylethylenediamine.



Scheme 3. Optimization of the reaction conditions in coupling of **5a** with *o*-iodotoluene.

Previous data¹² suggest that toluene is the solvent of choice for this reaction, so we attempted to find the ligand/base system, which allows the best substrate conversion. As a first step, a set of amine and phosphine ligands were tested (Table 1, entries 1–11). When using K₂CO₃ as the base, the monochelating (S)- α -phenylethylamine (Table 1, entry 3) produces **6a** with the highest yield. Other commonly used monoaza-ligands, such as L-proline¹⁷ (Table 1, entry 1) or 2-picolinic acid¹⁸ (Table 1, entry 2) afforded less of the **6a** product. For diamines, DMEDA, which has been shown by Buchwald and co-workers to be very effective for the coupling of secondary phosphines with aryl and vinyl halides,^{12a} afforded **6a** in only 29% yield (Table 1, entry 5); TMEDA was found to give **6a** in 77% yield, but this is still less effective than (S)- α -phenylethylamine. Mono- and diphosphines (Table 1, entries 9–11) could be used to transform **5a** into **6a** in relatively yields, but difficulties in separation of the product from the oxidized ligands made their use inconvenient.

In the second step, several bases were tested in the model reaction (Table 1, entries 12–15). However, all of them were less effective than potassium carbonate, so all further experiments were performed in the presence of this base.

The optimization of the ligand/base combination gave us a chance to take a closer look at the ability of the system to catalyze the coupling of secondary phosphine oxides with aryl halides. To provide a broader view of the compatibility of secondary phosphine oxides with the coupling reaction we chose diphenylphosphine oxide (**5a**), *o*-anisylphenylphosphine oxide (**5b**), methylphenylphosphine oxide (**5c**) and *tert*-butylphenylphosphine oxide (**5d**), di-*n*-hexylphosphine oxide (**5e**), and di-*c*-hexylphosphine oxide (**5f**) as model substrates (Table 2, Scheme 4).

The data presented in Table 2 show that all model secondary phosphine oxides reacted efficiently with the corresponding aryl halides and gave tertiary phosphine oxides in good to excellent yields. Further, diphenylphosphine oxide (**5a**) afforded good yields of **6a** and **6b** in reactions with *o*-substituted aryl iodides; similarly, *o*-anisylphenylphosphine oxide (**5b**) also reacted either with bulky aryl iodides (1-iodonaphthalene, *o*-iodotoluene) or with sterically non-demanding aryl iodides (2-iodonaphthalene, *p*-iodotoluene, *m*-xylyl iodide) to give the corresponding products in good yields. The presence of amino or bromo functionalities in the *para* position was very well tolerated, and coupling of **5b** with methyl *o*-iodobenzoate under the standard reaction conditions also gave the *ortho*-carboxy-functionalized triarylphosphine oxide in 86% yield.

In our previous paper, we described the transformation of diphenylmethylphosphine oxide into methylphenylphosphine oxide (**5c**),¹⁶ and we have also applied this precursor in coupling reactions with aryl iodides. In all cases the reaction led to formation of the corresponding diarylmethylphosphine oxides **6k–n** in very good yields. This two-step transformation can be regarded as a practical method for exchanging arene groups in arylmethylphosphine oxides. Similarly, the use of bulky phosphine oxide **5d** afforded the corresponding coupling products **6o–r** in good to excellent yields.

The coupling of dialkylphosphine oxides **5e** and **5f** with various aryl halides was also attempted. In all cases, the coupling product was formed efficiently; however, in some cases, the use of a two-fold excess of aryl halide was necessary to keep the yield high. The starting material was 2-bromopyridine in the case of 2-pyridylphosphine oxides **6s** and **6v** and this indicates that aryl bromides might also find application in coupling reactions with secondary phosphine oxides.

The use of a chiral amine ligand could lead to the formation of enantioselectively enriched products, however, chiral HPLC analysis of **6k–n** showed that in all cases racemates were formed, regardless of the ligand used in the coupling protocol ((S)- α -phenylethylamine, L-proline or (R)-BINAP).

Attempted coupling of phosphine oxides **5b** and **5d** with *p*-bromiodobenzene afforded the reactive bromo-substituted tertiary arylphosphine oxides **6g** and **6q**. The more interesting introduction of an aryl fragment possessing a *o*-bromo functionality, which might be used the synthesis of symmetrically- or unsymmetrically-substituted *ortho*-(diphosphorus-substituted) arenes, was also attempted (Scheme 5).

However, reaction of **5a** with *o*-dibromobenzene **7a** failed to provide any products under the standard reaction conditions. The related reaction of **5a** with *o*-bromiodobenzene **7b** provided the corresponding diphosphine dioxide **8a** in 43% yield. These results can be explained in terms of differences in the reactivity of carbon–bromide and carbon–iodine bonds. The more reactive carbon–iodine bond enters the reaction with the secondary phosphine oxide to give the intermediate *o*-bromophenyl-substituted tertiary phosphine oxide, which undergoes a second coupling reaction at the carbon–bromine bond. The presence of

Download English Version:

<https://daneshyari.com/en/article/5218580>

Download Persian Version:

<https://daneshyari.com/article/5218580>

[Daneshyari.com](https://daneshyari.com)