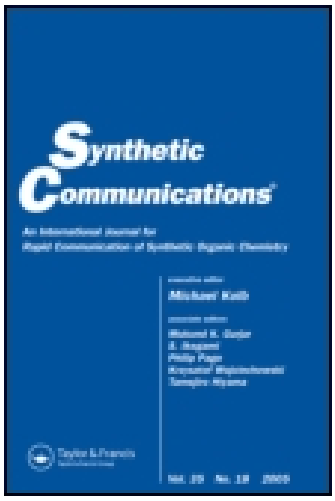

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HYPERVALENT IODINE IN SYNTHESIS. 52. PALLADIUM-CATALYZED ARYLATION OF *O,O*-DIALKYL PHOSPHITES WITH DIARYLIODONIUM SALTS: A CONVENIENT METHOD FOR SYNTHESIS OF ARYLPHOSPHONATES

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ABSTRACT

Palladium-catalyzed coupling reaction of diaryliodonium salts with *O,O*-dialkyl phosphites gave arylphosphonates in good yields.

The synthesis of arylphosphonates as precursors of phosphorous heterocycles or phosphorus analogs of heterocyclic compounds[1] is of considerable interest. A number of methods have been described for synthesis of arylphosphonates. For example, substitution of aryl halides with trialkyl

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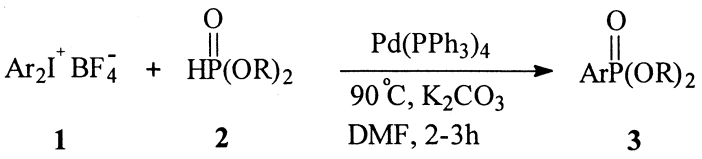
phosphites in the presence of nickle[2] or copper[3] catalyst; coupling of aryl halides or triflates with dialkyl phosphites in the presence of palladium catalyst,[4] the reaction of diaryliodonium salts with trialkyl phosphites;[5] the quenching of aryllithium derivatives with diethyl chlorophosphate;[6] the anodic[7] or chemical oxidation[8] of a mixture of arenes and tri- or dialkyl phosphites; the photoactivated substitution of halogenoanilines with diethyl phosphite;[9] the reaction of Grignard reagent with diethyl cyanophosphonate.[10] However, most of these methods have certain disadvantages, such as the use of excess phosphites, harsh reaction conditions or low yield. Therefore, there is still a need to develop an efficient method for the synthesis of arylphosphonates.

In our previous reports dealing with synthetic applications of hypervalent iodine compounds,[11] it has been shown that diaryliodonium salts are high reactive substances in many palladium-catalyzed arylating reactions. In our continuing studies on the palladium-catalyzed arylation, we have explored the palladium-catalyzed arylation to carbon-phosphorus bond forming reaction. Here we report the results which are summarized in Scheme 1 and Table 1. The products were characterized by IR, ^{1}H-NMR and comparison with literature value.



1 2 3

Scheme 1.

We have found that in the presence of K_2CO_3 the palladium-catalyzed arylation of *O,O*-dialkyl phosphites with diaryliodonium salts takes place smoothly and reaches completion within 2–3 h at 90°C in DMF. We examined the effect of a variety of catalysts for the reaction of diphenyliodonium salt with *O,O*-dipropyl phosphite in the presence of potassium carbonate. As can be seen in Table 1 (Entries 1, 2, 3, 4), tetrakis(triphenylphosphine) palladium was found to be the most effective catalyst for the reaction. In the absence of palladium catalyst, the reaction can hardly proceed (Entry 5), so palladium catalyst is essential for this reaction. Several diaryliodonium salts containing various substituents such as methyl, chloro, methoxy and nitro groups, were successfully arylated with *O,O*-dialkyl phosphites.

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Table 1. Palladium-Catalyzed Coupling of Diaryliodonium Salts and Dialkylphosphites

Entry	Catalyst	Product	Yield (%)[a]
1	$Pd(PPh_3)_4$	$PhP(O)(OPr\text{-}n)_2$ **3a**	98
2	$PdCl_2(PPh_3)_2$	**3a**	74
3	$PdCl_2$	**3a**	70
4	$Pd(OAc)_2$	**3a**	66
5	/	**3a**	trace
6	$Pd(PPh_3)_4$	$PhP(O)(OEt)_2$ **3b**	92
7	$Pd(PPh_3)_4$	$PhP(O)(OPr\text{-}i)_2$ **3c**	98
8	$Pd(PPh_3)_4$	$PhP(O)(OBu\text{-}n)_2$ **3d**	91
9	$Pd(PPh_3)_4$	$p\text{-}TolP(O)(OEt)_2$ **3e**	86
10	$Pd(PPh_3)_4$	$p\text{-}TolP(O)(OPr\text{-}n)_2$ **3f**	86
11	$Pd(PPh_3)_4$	$p\text{-}TolP(O)(OPr\text{-}i)_2$ **3g**	89
12	$Pd(PPh_3)_4$	$p\text{-}TolP(O)(OBu\text{-}n)_2$ **3h**	82
13	$Pd(PPh_3)_4$	$p\text{-}ClC_6H_4P(O)(OPr\text{-}i)_2$ **3i**	78
14	$Pd(PPh_3)_4$	$p\text{-}ClC_6H_4P(O)(OPr\text{-}n)_2$ **3j**	82
15	$Pd(PPh_3)_4$	$m\text{-}NO_2C_6H_4P(O)(OEt)_2$ **3k**	72
16	$Pd(PPh_3)_4$	$p\text{-}CH_3OC_6H_4P(O)(OEt)_2$ **3l**	83

[a]Isolated yields based on diaryliodonium salts.

We previously reported a method of preparing arylphosphonates by the reaction of diaryliodonium salts with dialkyl phosphite salts.[12] But present method is more convenient. There is no need to use strong base and the reaction time is shorter.

In summary, we provide an effective synthesis for arylphosphonates by palladium-catalyzed arylation of *O,O*-dialkyl phosphites with diaryliodonium salts. It has some advantages over others such as mild reaction conditions, simple procedure and good yields. It also extends the palladium-catalyzed arylation to carbon-heteroatom bond forming reaction with diaryliodonium salts.

EXPERIMENTAL

^1H NMR spectra were recorded on PMK-60 spectrometer using CCl_4 as the solvent with TMS as an internal standard. IR spectra were determined on PE-683 Infrared spectrophotometer.

Typical procedure for preparation of dialkyl arylphosphonate: A mixture of $Ph_2I^+BF_4^-$ (360 mg, 1 mmol), K_2CO_3 (166 mg, 1.2 mmol), Pd $(PPh_3)_4$

(60 mg, 0.05 mmol), DMF (6 mL) and dialkyl phosphonate (0.2 mL, 1.2 mmol) was stirred at 90°C for 2 h under nitrogen atmosphere, then diluted with saturated aqueous NH_4Cl (20 mL) and extracted with ether (15 mL × 3). The combined organic layer was washed with brine and dried over anhydrous Na_2SO_4. After the removal of the solvent in vacuum, the residue was isolated by TLC with c-hexane-EtOAc (2 : 1) as developer to give pure dipropyl phenylphosphonate (**3a**) 235 mg, 98% yield.

Spectroscopic Data for the Product

Dipropyl phenylphosphonate **3a**: oil, bp 115°C/2 Torr (lit[13] bp 106–108°C/1 Torr), ^{1}H NMR, δ_H 0.9 (t, 6H), 1.6 (m, 4H), 3.9 (m, 4H), 7.6 (m, 3H), 7.9 (m, 2H). IR (film), ν_{max} 1255 (P=O), 1030 (P-O-C), 980 cm^{-1} (Ar-P).

Diethyl phenylphosphonate **3b**: oil, bp 112°C/2 Torr (lit[2] bp 96–98°C/0.2 Torr), ^{1}H NMR, δ_H 1.28 (t, 6H), 4.13 (m, 4H), 7.7 (m, 3H), 8.1 (m, 2H). IR (film), ν_{max} 1250, 1030, 965 cm^{-1}.

Diisopropyl phenylphosphonate **3c**: oil, bp 131°C/2 Torr (lit[2] bp 96–97°C/0.1 Torr), ^{1}H NMR, δ_H 1.25 (m, 12H), 4.6 (m, 2H), 7.5 (m, 3H), 7.8 (m, 2H). IR (film), ν_{max} 1250, 1010, 980 cm^{-1}.

Dibutyl phenylphosphonate **3d**: oil, 154°C/2 Torr (lit[14] 166°C/3.8 Torr), ^{1}H NMR, δ_H 0.85 (t, 6H), 1.5 (m, 8H), 3.95 (m, 4H), 7.5 (m, 3H), 7.85 (m, 2H). IR (film), ν_{max} 1250, 1025, 970 cm^{-1}.

Diethyl *p*-tolylphosphonate **3e**: oil, 179°C/2 Torr (lit[2] bp 118–119°C/0.05 Torr), ^{1}H NMR, δ_H 1.23 (t, 6H), 2.33 (s, 3H), 4.1 (m, 4H), 7.3 (m, 2H), 7.7 (m, 2H). IR (film), ν_{max} 1250, 1030, 970 cm^{-1}.

Dipropyl *p*-tolylphosphonate **3f**: oil, 120°C/2 Torr (lit[13] bp 110–112°C/1 Torr), ^{1}H NMR, δ_H 0.88 (t, 6H), 1.55 (m, 4H), 2.35 (s, 3H), 3.9 (m, 4H), 7.3 (m, 2H), 7.72 (m, 2H). IR (film), ν_{max} 1250, 1050, 990 cm^{-1}.

Diisopropyl *p*-tolylphosphonate **3g**: oil, 118°C/2 Torr (lit[13] 98–100°C/1 Torr), ^{1}H NMR, δ_H 1.25 (m, 12H), 2.35 (s, 3H), 4.6 (m, 2H), 7.25 (m, 2H), 7.7 (m, 2H). IR (film), ν_{max} 1250, 1010, 980 cm^{-1}.

Dibutyl *p*-tolylphosphonate **3h**: oil, 164°C/2 Torr (lit[15] 148°C/0.7 Torr), ^{1}H NMR, δ_H 0.88 (t, 6H), 1.4 (m, 8H), 2.37 (s, 3H), 4.0 (m, 4H), 7.35 (m, 2H), 7.75 (m, 2H). IR (film), ν_{max} 1250, 1010, 970 cm^{-1}.

Diisopropyl *p*-chlorophenylphosphonate **3i**: oil, 145°C/2 Torr (lit[16] oil, bp was not reported) ^{1}H NMR, δ_H 1.25 (m, 12H), 4.6 (m, 2H), 7.25–7.9 (m, 4H). IR (film), ν_{max} 1250, 1020, 980 cm^{-1}.

Dipropyl *p*-chlorophenylphosphonate **3j**: oil, 142°C/2 Torr (lit[17] 148.5°C/3 Torr), ^{1}H NMR, δ_H 0.9 (t, 6H), 1.6 (m, 4H), 3.9 (m, 4H), 7.22–7.9 (m, 4H). IR (film), ν_{max} 1250, 1020, 980 cm^{-1}.

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Diethyl *m*-nitrophenylphosphonate **3k**: oil, 168°C/2 Torr (lit[18] 133–137°C/0.2 Torr), ^{1}H NMR, δ_H 1.23 (t, 6H), 4.1 (m, 4H), 7.3–8.0 (m, 4H). IR (film), ν_{max} 1250, 1010, 980 cm^{-1}.

Diethyl *p*-methoxyphenylphosphonate **3l**: oil, 173°C/2 Torr (lit[2] bp 168–169°C/1.5 Torr), ^{1}H NMR, δ_H 1.2 (t, 6H), 3.9 (m, 4H), 3.7 (s, 3H), 7.25–7.8 (m, 4H). IR (film), ν_{max} 1250, 1020, 960 cm^{-1}.

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