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A Convenient Access to Triarylphosphines with Fluorous Phase Affinity

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Abstract:

Perfluorocarbon-soluble triarylphosphines with electronic properties similar to those of tris(*p*-methoxyphenyl)phosphine can be easily prepared through *O*-alkylation of tris(*p*-hydroxyphenyl)phosphine oxide and subsequent reduction with trichlorosilane. © 1999 Elsevier Science Ltd. All rights reserved.

Key words: phosphines, phosphine oxides, perfluorinated solvent, perfluoroalkyl compounds.

There is an increasing interest in the development of new liquid-liquid biphasic catalytic systems [1]. One of the most interesting, recent advances in this field is based on the thermo- and pressure-controlled miscibility of perfluorocarbons (fluids made up only of F and C, or F, C and O, or F, C and N) with regular organic solvents [2]. At room temperature and under atmospheric pressure, perfluorocarbons (the so-called fluorous phase) are almost immiscible with solvents such as acetonitrile or toluene, whereas miscibility can sharply increase with temperature and pressure [3]. Biphasic systems can be thus obtained, in which a catalyst soluble in the fluorous phase is segregated from reagents and products, either during the whole process or during the work-up only. This approach brings about several advantages over classical homogeneous catalysis, including the easy and effective separation and recycling of the catalyst. Therefore, it is currently attracting the attention of many researchers [4]. As phosphines are playing a pivotal rôle in coordination chemistry and catalysis [5], it is little wonder that many efforts have been devoted to the synthesis of fluorous-soluble ligands of this class [6]. Fluorous affinity is achieved by introducing a certain number of perfluoroalkyl tails (R_F) of appropriate length in the structure of the ligand. An alkyl spacer can be interposed between the donor atom and the R_F substituents, in order to shield phosphorous from the strong electron-withdrawing of the latter [6]. This

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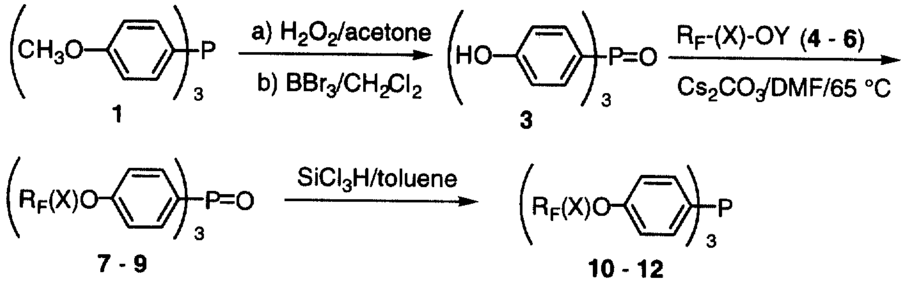
kind of ligand proved to be very efficient in fluorous-organic catalytic reactions such as the hydroformylation of alkenes [7]. Nevertheless, a further modulation of the stereoelectronic properties of phosphines is required for an efficient approach to many potential applications of fluorous-organic biphasic systems, for instance hydrogenation reactions and palladium(0)-catalyzed substitution of allylic substrates. The obstacle can be overcome by the use of perfluorocarbon-soluble triarylphosphine [8], whose stereoelectronic properties can be tuned by the introduction of proper substituents on the phenyl rings.

Fluorous trialkyl- and triarylphosphines has been so far prepared by reacting perfluoroalkylated organometallic building-blocks with PCl_3 [7, 8], or alkenes $R_F(CH_2)_nCH{=}CH_2$ with PH_3 [6]. Here we describe a new simple and very convenient method for the preparation of electron-rich triarylphosphines that exhibit fluorous affinity (Scheme 1).



	R_F	X	Y	Yield %
4	C_7F_{15}	CH_2	$O_2SC_4F_9$	
5	C_8F_{17}	$(CH_2)_3$	I	
6	$CF_3O(CF_2O)_p(CF_2CF(CF_3)O)_qCF_2$ $\bar{q} = 3.38$; $\bar{p} = 0.11$	$CH_2O(CH_2)_2$	OTs	
7	C_7F_{15}	CH_2		75
8	C_8F_{17}	$(CH_2)_3$		42
9	$CF_3O(CF_2O)_p(CF_2CF(CF_3)O)_qCF_2$ $\bar{q} = 3.38$; $\bar{p} = 0.11$	$CH_2O(CH_2)_2$		80
10	C_7F_{15}	CH_2		90
11	C_8F_{17}	$(CH_2)_3$		92
12	$CF_3O(CF_2O)_p(CF_2CF(CF_3)O)_qCF_2$ $\bar{q} = 3.38$; $\bar{p} = 0.11$	$CH_2O(CH_2)_2$		87

Scheme 1: Synthesis of phosphines **10-12**.

Tris(*p*-methoxyphenyl)phosphine **1** is commercially available or, alternatively, it can be obtained on multigrams scale following a well-established procedure [9]. The corresponding phosphine oxide **2** was prepared in 95% yield by oxidation with 10% H_2O_2 and then demethylated with BBr_3 affording tris(*p*-hydroxyphenyl)phosphine oxide **3** in 85% yield [9b]. Phosphine oxide **3** can be then functionalized using no special precaution with a variety of perfluoroalkyl derivatives, here exemplified by compounds **4-6** [10].

Perfluoroalkyl alcohols of the formula R_FCH_2OH, with $R_F = C_7F_{15}$, C_8F_{17}, C_9F_{19}, $C_{11}F_{23}$, $C_{13}F_{27}$, are commercially available. The hydroxyl function can be converted into a good leaving group by treating the alcohol with a slight excess of $C_4F_9SO_2F$ in Et_2O in the presence of Et_3N. Accordingly, butaflate **4** was obtained in 95% yield and, contrary to the report in the literature [11], it was pure enough to be used directly as *O*-alkylating agent. Addition of allyl alcohol to R_FI ($R_F = C_8F_{17}$), followed by deiodination with Bu_3SnH and then reaction of $R_F(CH_2)_3OH$ with KI in H_3PO_4/P_2O_5, afforded iodide **5** in 50% overall yield [12]. Finally, tosylate **6** was prepared as previously described by one of us [13]. Once obtained, phosphine oxides **7-9** can be stored on the shelf and reduced when needed to the corresponding phosphines **10-12** in 85-90% yield [14]. When reduction with $HSiCl_3$ was carried out on a millimolar scale, only the desired phosphine was detected by NMR analysis.

The introduction of a $-(CH_2)_nO-C_6H_4-$ spacer is very effective in minimizing the strong electron withdrawing effect of the fluorous ponytails on the phosphorus atom. Indeed, a comparison of the ^{31}P chemical shifts for phosphine ligands **10-12** with **1**, a mildly basic triarylphosphine [15], shows only a minor variation (Table 1).

Phosphine	$\delta\ ^{31}P\ (CDCl_3)$	$\delta\ ^{1}H\ (CDCl_3)$
1	- 9.4	7.23 (6H, dd, $^3J_{PH}$ = 7.4 Hz, $^3J_{HH}$ = 8.8 Hz), 6.88 (6H, dd, $^4J_{PH}$ = 1.1 Hz, $^3J_{HH}$ = 8.8 Hz), 3.80 (9H, s)
10	- 9.5	7.25 (6H, dd, $^3J_{PH}$ = 7.0 Hz, $^3J_{HH}$ = 8.8 Hz), 6.93 (6H, dd, $^4J_{PH}$ = 0.7 Hz, $^3J_{HH}$ = 8.8 Hz), 4.04 (6H, t, $^3J_{FH}$ = 11.9 Hz)
11	- 9.6	7.22 (6H, dd, $^3J_{PH}$ = 7.3 Hz, $^3J_{HH}$= 8.8 Hz), 6.86 (6H, dd, $^4J_{PH}$ = 1.1 Hz, $^3J_{HH}$ = 8.8 Hz), 4.03 (6H, t, $^3J_{HH}$ = 5.7 Hz), 2.40-2.20 (6H, m), 2.16-2.04 (6H, m)
12	- 9.7	7.20 (6H, dd, $^3J_{PH}$ = 7.3 Hz, $^3J_{HH}$ = 8.3 Hz), 6.87 (6H, dd, $^4J_{PH}$ = 0.9 Hz, $^3J_{HH}$ = 8.3 Hz), 4.18-4.05 (6H, m), 3.99-3.68 (12H, m)

Table 1: Comparison of NMR Data for Phosphines **1** and **10-12**.

The new ligands are soluble in some organic solvents, for instance Et_2O and $CHCl_3$, but also in perfluorocarbons such as perfluorooctane. Although the partition coefficient has not been determined quantitatively, it is noteworthy that in a preliminar experiment we were able to use **11** as a fluorous ligand in palladium(0)-catalyzed nucleophilic substitution of cinnamyl methyl carbonate with dimethyl malonate. Reaction was carried out in a biphasic mixture toluene/ perfluorooctane and the results, manyfold recycles of the catalyst included, agreed well with those already obtained by us in the presence of another fluorinated triarylphosphine [16].

In conclusion, we have shown that fluorous soluble triarylphosphines with electronic properties close to that of the mildly basic tris(*p*-methoxyphenyl)phosphine **1** can be prepared effectively by *O*-alkylation of the easily available phosphine oxide **2**. Extension of this strategy to the synthesis of phosphines in which each aryl group bears more than one fluorinated tail as well as coordination studies are under way and will be reported in due course.

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[10] **Typical procedure**: A mixture of 1 mmol of phosphine oxide **3**, 3.3 mmol of butaflate **4**, 6.6 mmol of Cs_2CO_3 in 10 mL of DMF was stirred at 65 °C under N_2 for 8 hours. The suspension was cooled at room temperature, poured into H_2O (10 mL), and then extracted with Et_2O (3 x 15 mL). The organic phase was dried over $MgSO_4$, and the solvent evaporated to give a cream solid that was further purified by column chromatography on silica gel (CH_2Cl_2/MeOH) to give phosphine oxide **7** (75% yield). ^1H NMR ($CDCl_3$) δ 7.62 (6H, dd, $^3J_{PH} = 11.4$ Hz, $^3J_{HH} = 8.8$ Hz), 7.03 (6H, dd, $^4J_{PH} = 1.8$ Hz, $^3J_{HH} = 8.8$ Hz), 4.51 (6H, t, $^3J_{FH} = 12.1$ Hz); ^{13}C NMR ($CDCl_3$) δ 160.1 (s), 134.1 (d, $^2J_{PC} = 11.6$ Hz), 127.1 (d, $^1J_{PC} = 110.2$ Hz), 114.9 (d, $^3J_{PC} = 13.6$ Hz), 65.0 (t, $^2J_{FC} = 16.0$ Hz); ^{31}P NMR ($CDCl_3$) δ 27.6. To a mixture of phosphine oxide **7** (736 mg, 0.5 mmol) and freshly distilled triethylamine (300 µL, 2.16 mmol) in dry toluene (3 mL) was cautiously added $HSiCl_3$ (200 µL, 2 mmol) under argon at room temperature. The mixture was warmed to 130 °C and stirred for 3 hours; after been cooled to 5 °C, the solution was treated by precooled deaerated 2N NaOH (10 mL). The aqueous layer was extracted with deareated Et_2O (3 x 10 mL). The combined organic layers were washed twice with deaerated water (10 mL), dried on Na_2SO_4. Evaporation of the solvent gave phosphine **10** as a white solid (657 mg, 90%).

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