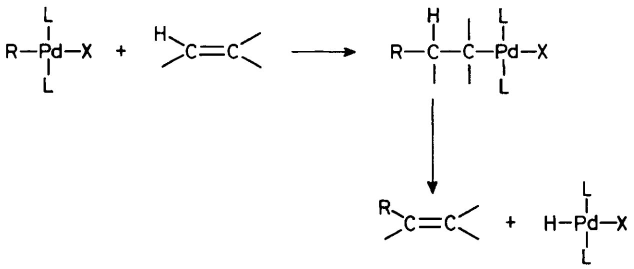
Palladium-catalysed Vinylation of Organic Halides under Solid–Liquid Phase Transfer Conditions

Tuyet Jeffery

ER 12 du CNRS, Laboratoire de Chimie de l'Ecole Normale Supérieure, 24 Rue Lhomond, 75231, Paris Cédex 05, France

Heck-type reactions involving organic halides proceed readily at or near room temperature when performed under solid–liquid phase transfer conditions.

Heck-type reactions are a well known method for forming carbon–carbon bonds at unsubstituted vinylic positions, involving *cis*-addition of an organopalladium complex to a double bond followed by a palladium hydride *cis*-elimination[1] (Scheme 1).



X = halide
L = ligand

Scheme 1

Several methods are available to generate the organopalladium intermediates.[2] More interesting, in organic synthesis, is their generation from readily available organic halides and a catalytic amount of a zerovalent palladium complex, preformed or formed *in situ*. The Pd-catalysed reaction of organic halides with vinylic substrates has therefore attracted much attention: the many results obtained since the initial studies[3] have been reviewed recently.[4] However, a disadvantage of Heck-type reactions involving organic halides is the relatively high temperature (*ca.* 100 °C) required, compared to those employing organometallic reagents as starting materials.[2] Modified conditions have recently been reported[5] which allow this type of reaction to be performed at lower temperatures (25—60 °C), but large amounts of the palladium catalyst were required (10, 20, or 100 mole %) and the reaction was only successful with vinylic halides and aromatic halides having a nitro substituent.

We now report that the Pd-catalysed vinylation of organic halides can readily proceed at or near room temperature under solid–liquid phase transfer conditions, using tetrabutylammonium chloride as the phase transfer agent and sodium hydrogen carbonate as base.

A high yield of methyl *E*-3-phenylpropenoate can be obtained at 30 °C in *N,N*-dimethylformamide (DMF) from iodobenzene and methyl acrylate in the presence of a catalytic amount of palladium acetate (1 or 2 mole %), sodium hydrogen carbonate, and tetrabutylammonium chloride (Table 1, entries 4 and 5). No reaction was observed at the same temperature in the absence of tetrabutylammonium chloride. The yields and reaction times depend upon the nature and the concentration of the phase transfer agent. Tetrabutylammonium chloride is much more efficient than tetrabutylammonium hydrogen sulphate, trioctylmethylammonium chloride, or tetrabutylammonium bromide, and the reaction rate increases with increasing concentration of tetrabutylammonium chloride (Table 1, entries 1, 2, 3, and 5).

Various α,β-unsaturated esters, ketones, and aldehydes have been obtained at 20—30 °C in high yield with high regio- and stereo-selectivity (Table 2). These mild conditions for the Pd-catalysed vinylation of organic halides have been successfully extended to thermally unstable vinylic substrates such as methyl vinyl ketone and acrolein.

When allylic alcohols are used as the olefinic compounds, it is known that the Heck-type reaction of aromatic halides leads to the formation of carbonyl compounds (Scheme 2).[4] This reaction also proceeds near room temperature when performed under solid–liquid phase transfer conditions. As shown in Table 3, no reaction was observed at 30 °C with iodobenzene and prop-2-en-1-ol in the presence of palladium acetate (1 or

Table 1. Pd-catalysed reaction of PhI with $CH_2=CHCO_2Me$ at 30 °C[a]

Entry	Equiv. of NBu_4Cl	Reaction time/h	% Conversion[b]	% Yield[b] of *E*-$PhCH=CHCO_2Me$
1	0	24	0	0
2	0.1	24	20	20
3	0.4	24	54	53
4	0.4	48	100	94[c]
5	0.8	24	97	97

[a] Carried out in DMF in the presence of $Pd(OAc)_2$ (0.01 or 0.02 equiv.), $NaHCO_3$ (2.5 equiv.), and NBu_4Cl (as indicated). [b] Determined by g.l.c. analysis unless otherwise stated. [c] Yield of isolated product.

Table 2. Regio- and stereo-selective Pd-catalysed synthesis of unsaturated esters, ketones, and aldehydes from organic halides and vinylic substrates.[a]

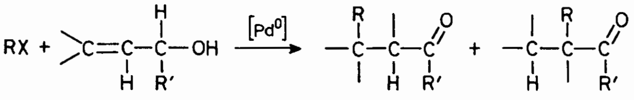
Organic halide	Vinylic substrate	Reaction Temp./°C	Time/days[b]	Product	% Yield[c]
PhI	$CH_2=CHCO_2Me$	30	1	*E*-$PhCH=CHCO_2Me$	94
m-MeC_6H_4I	"	"	"	*E*-*m*-$MeC_6H_4CH=CHCO_2Me$	94
p-ClC_6H_4I	"	20	2.5	*E*-*p*-$ClC_6H_4CH=CHCO_2Me$	98
E-$C_4H_9CH=CHI$	"	30	2	*E,E*-$C_4H_9CH=CHCH=CHCO_2Me$	80[d]
				E,Z-$C_4H_9CH=CHCH=CHCO_2Me$	5[d]
PhI	$CH_2=CHCOMe$	25	2	*E*-$PhCH=CHCOMe$	98
m-MeC_6H_4I	"	25	3	*E*-*m*-$MeC_6H_4CH=CHCOMe$	97
p-ClC_6H_4I	"	25	2	*E*-*p*-$ClC_6H_4CH=CHCOMe$	98
p-$MeOC_6H_4I$	"	25	3	*E*-*p*-$MeOC_6H_4CH=CHCOMe$	97
E-$C_4H_9CH=CHI$	"	"	"	*E,E*-$C_4H_9CH=CHCH=CHCOMe$	88[d]
				E,Z-$C_4H_9CH=CHCH=CHCOMe$	6[d]
PhI	$CH_2=CHCHO$	20	2.5	*E*-$PhCH=CHCHO$	90
m-MeC_6H_4I	"	"	"	*E*-*m*-$MeC_6H_4CH=CHCHO$	87
p-ClC_6H_4I	"	"	"	*E*-*p*-$ClC_6H_4CH=CHCHO$	89

[a] RX(1 equiv.), vinylic substrate (1.5—2 equiv.), $Pd(OAc)_2$ (0.01 or 0.02 equiv.), $NaHCO_3$ (2.5 equiv.), NBu_4Cl (1 equiv.), in DMF. [b] Reaction conditions are not optimized; the reaction may be complete in a shorter reaction period. [c] Yield of spectroscopically pure product, isolated by chromatography on silica gel, unless otherwise stated. [d] Determined by g.l.c. analysis.

Table 3. Regioselective Pd-catalysed reactions of aromatic halides with allylic alcohols at 25—30 °C °.[a]

Organic halide	Allylic alcohol	Equiv. of NBu_4Cl	% Conversion[b]	Product (% yield)[b]
PhI	$CH_2=CHCH_2OH$	0	0	$PhCH_2CH_2CHO$ (0)
"	"	0.15	25	" (19)
"	"	0.4	61	" (47)
"	"	0.7	74	" (63)
"	"	0.95	100	" (91) (82)[c]
m-MeC_6H_4I	"	1	100	*m*-$MeC_6H_4CH_2CH_2CHO$ (90)[c]
p-ClC_6H_4I[d]	"	1	100	*p*-$ClC_6H_4CH_2CH_2CHO$ (85)[c]
m-MeC_6H_4I	$CH_2=CHCH(OH)Et$	1	100	*m*-$MeC_6H_4CH_2CH_2COEt$ (90)[c]
p-ClC_6H_4I[d]	"	1	100	*p*-$ClC_6H_4CH_2CH_2COEt$ (94)[c]

[a] RX (1 equiv.), allylic alcohol (1.5 equiv.), $Pd(OAc)_2$ (0.01 or 0.02 equiv.), $NaHCO_3$ (2.5 equiv.), NBu_4Cl (as indicated), in DMF, 24 h, 30 °C, unless otherwise stated. [b] Determined by g.l.c. analysis unless otherwise stated. [c] Yield of spectroscopically pure product, isolated by chromatography on silica gel. [d] Reaction temperature 25 °C.



Scheme 2

2 mole %) and sodium hydrogen carbonate in DMF, unless tetrabutylammonium chloride was present. The reaction rate was again found to increase with increasing concentration of tetrabutylammonium chloride. Various β aryl ketones and aldehydes have thus been prepared from aromatic halides and allylic alcohols, at 25—30 °C, in high yields and with high regioselectivity (Table 3).

These solid–liquid phase transfer conditions allowing Heck-type reactions involving organic halides to proceed at or near room temperature may give this reaction a wider applicability in organic synthesis.

We thank Dr. G. Linstrumelle for his interest and critical discussions and the CNRS for financial support.

Received, 7th June 1984; Com. 792

References

1 R. F. Heck, *J. Am. Chem. Soc.*, 1968, **90**, 5518.
2 B. M. Trost and T. R. Verhoeven in 'Comprehensive Organometallic Chemistry', eds. G. Wilkinson, F. G. A. Stone, and E. W. Abel, Pergamon Press, Oxford, 1982, vol. 8, p. 799 and references cited therein.
3 M. Mizoroki, K. Mori, and A. Ozaki, *Bull. Chem. Soc. Jpn.*, 1971, **44**, 581; R. F. Heck and J. P. Nolley, *J. Org. Chem.*, 1972, **37**, 2320; M. Julia and M. Duteil, *Bull. Soc. Chim. Fr.*, 1973, 2790.
4 R. F. Heck, *Org. React.*, 1982, **27**, 345, and references cited therein.
5 F. E. Ziegler, U. R. Chakraborty, and R. B. Weisenfeld, *Tetrahedron*, 1981, **37**, 4035.