Wittig Resins: The Preparation and Application of Insoluble Polymeric Phosphoranes

By S. V. McKinley* and J. W. Rakshys, jun.
(*The Dow Chemical Company, Eastern Research Laboratory, Wayland, Massachusetts* 01778)

Summary A solid-phase method has been applied to Wittig olefin synthesis; insoluble poly-*p*-styryldiphenylalkylidenephosphorane resins (III) have been prepared and treated with carbonyl compounds to give olefins in good yield.

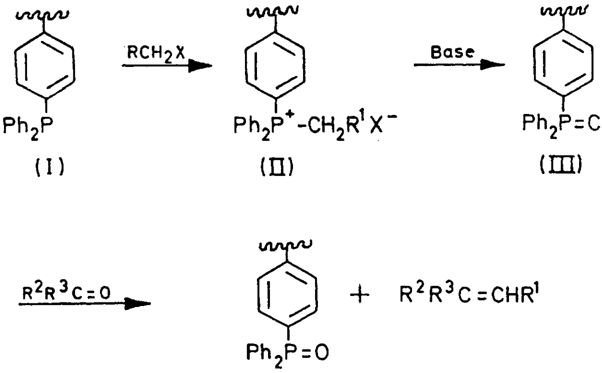
The application of solid-phase functionalized polymers as reaction substrates is of current interest, and has been explored extensively in the multi-stage polypeptide synthesis,[1,2] although few examples of general synthetic nature have been reported.[3,4] We now report the preparation of polymeric phosphorane derivatives (III; $R^1 = H$, Me, or Ph) and their treatment with aromatic and aliphatic ketones and aldehydes [equation (1)] to afford a wide variety of olefins in good yield. The use of the Wittig resin reagent (III) allows filtration of the olefinic product from the poly-phosphine oxide by-product.

Two approaches were used for the preparation of the ylide precursor, poly-*p*-styryldiphenylphosphine (I):

(a) *p*-Bromostyrene was suspension copolymerized with three parts of styrene and 2% divinylbenzene. The white solid beads of polymer were converted into the lithiopolymer with BuLi in benzene, and were then treated with chlorodiphenylphosphine to give partial incorporation of Ph_2P groups. The lithiation step was quantitative based on bromine analysis, but only *ca.* 60% of the theoretical number of Ph_2P groups were incorporated. This resulted in a resin containing *ca.* 1·0 mmol of functional group per gram.

(b) Alternatively, the monomer *p*-styryldiphenylphosphine was prepared[5] (70%) and then suspension copolymerized with three parts of styrene and 2% divinylbenzene. The final copolymer contained the expected proportion of phosphorus (*ca.* 1·5 mmol/g resin).

Polymer (I) was treated with various alkyl halides to give polymeric phosphonium salts (II). Me_2SO was a particularly effective solvent for alkylations with methyl and ethyl iodide, since it readily caused (II; R = H or Me; X = I) to swell. Polymer (II; R^1 = Ph) was obtained by alkylation with benzyl bromide, either neat or in solution in tetrahydrofuran (THF). In all cases the weight gain upon alkylation as well as phosphorus and halogen analyses confirmed the extent of alkylation to be *ca.* 85—100%.



(1)

The Wittig reaction[6] was carried out by suspending the polymer beads (II) in a mixture of THF and Me_2SO and adding an excess of methylsulphinyl carbanion (sodium salt). After several hours, unchanged base and alkali halide were removed by repeated washings of the beads. Finally (III), suspended in THF, was treated with an approximately stoicheiometric amount of carbonyl compound and allowed to react for several hours. The olefin was recovered as a THF solution by combining the supernatant fluid with several washings of the beads. Product yields and conversions of starting carbonyl compounds were obtained by quantitative g.l.c. techniques using standard solutions in direct comparisons.

The results of the carbonyl-olefination reactions are listed in the Table. The reactions proceed in reasonable yield with polymeric ylides of widely varying reactivity, *i.e.* highly reactive methylene, ethylidene, and moderated benzylidene derivatives using aromatic and aliphatic ketones and aldehydes. It is worth noting that conversion of the carbonyl compound is generally incomplete, suggesting that a portion of the resin sites is inaccessible for reaction. Yields in the Table are based on recovered carbonyl reactant in order to account for unavailable reaction sites, and in general compare favourably with yields reported for the same monomeric reactions. Yields based on initial carbonyl reactant are shown in parentheses.†

For the last two reactions listed in the Table the formation of *cis*- and *trans*-olefins was possible and the isomer distribution was determined. 84% of *cis*-β-methylstyrene was formed while stilbene contained 58% of the *trans*-isomer. Nearly identical ratios of 87%[7a] and 56%,[7b] respectively have been reported for the analogous monomeric Wittig reactions in similar solvents and in the absence of alkali halide salts. Although limited to only two cases, this observation suggests that the reaction mechanism in the resin closely resembles that in solution.[6]‡

TABLE. *Olefin yields in Wittig reactions using poly*-p-*styryldiphenylalkylidene-phosphoranes* (III)[a] *with carbonyl compounds*

(III) R^1	R^2R^3CO	Product	Yield[b] (%)	Lit. yield (%)
H	Cyclohexanone	Methylenecyclohexane	90(63)	52[c]
H	Ph_2CO	$Ph_2C{=}CH_2$	94(72)	84[d]
H	PhCHO	$PhCH{=}CH_2$	82(50)	67[c]
H	PhCOMe	$PhC(Me){=}CH_2$	76(14)	74[c]
H	$Me[CH_2]_4{\cdot}CHO$	$Me[CH_2]_4{\cdot}CH{=}CH_2$	58(56)	—
Me	Cyclohexanone	Ethylidenecyclohexane	90(50)	—
Me	Ph_2CO	$Ph_2C{=}CHMe$	93(24)	98[e]
Me	PhCHO	$PhCH{=}CHMe$	[f]	—
Ph	PhCHO	$PhCH{=}CHPh$	72(35)	82[c]

[a] Data were obtained using polymers prepared by method (b) (see text). [b] Yields are based on amount of carbonyl reactant consumed. Yields based on the initial amount of carbonyl are in parentheses. [c] G. Wittig and U. Schöllkopf, *Chem. Ber.*, 1954, **97**, 1318. [d] G. Wittig and G. Geissler, *Annalen*, 1953, **580**, 44. [e] E. J. Corey and M. Chaykovsky, *J. Amer. Chem. Soc.*, 1962, **84**, 866. The geometric isomer ratio only was determined: 84% *cis*, 16% *trans* (see text).

We thank Drs. J. Martin, H. Small, and R. Hansen for helpful discussions.

(*Received, November 2nd*, 1971; *Com.* 1904.)

† Side reactions of the carbonyl compounds independent of the resin are possible. However, in one case where benzyl alcohol was a possible product of the base-catalysed Cannizzaro reaction of benzaldehyde, we observed less than 1%, in contrast to the observation of Camps, *et al.* [4b]

‡ In other types of systems significant differences in the course of a reaction on a resin and in solution have been reported.[3b,c]

[1] R. B. Merrifield, *J. Amer. Chem. Soc.*, 1963, **85**, 2149.

[2] J. M. Stewart and J. D. Young, 'Solid Phase Peptide Synthesis,' Freeman, San Francisco, 1969.

[3] Some of the more recent examples are: (a) T. Takagi, *Polymer Letters*, 1967, **5**, 1031; (b) J. I. Crowley and H. Rapoport, *J. Amer. Chem. Soc.*, 1970, **92**, 6363; (c) A. Patchornik and M. A. Kraus, *ibid.*, 1970, **92**, 7587.

[4] (a) F. Camps, J. Castells, M. J. Ferrando, and J. Font, *Tetrahedron Letters*, 1971, 1713; (b) F. Camps, J. Castells, J. Font, and F. Vela, *ibid.*, p. 1715.

[5] R. Rabinowitz and R. Marcus, *J. Org. Chem.*, 1961, **26**, 4157.

[6] The Wittig reaction in solution is discussed in: A. W. Johnson, 'Ylid Chemistry,' Academic Press, New York, 1966.

[7] M. Schlosser in 'Topics in Stereochemistry,' vol. 5, ed. E. L. Eliel and N. L. Allinger, Wiley–Interscience, New York, 1970 (a) p. 15; (b) p. 10.