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ENAMINE-ALKENEPHOSPHONATE CYCLOADDITIONS. CYCLOBUTENEPHOSPHONATES.

Stephen D. Darling* and N. Subramanian
Department of Chemistry, The University of Akron, Akron, Ohio 44325

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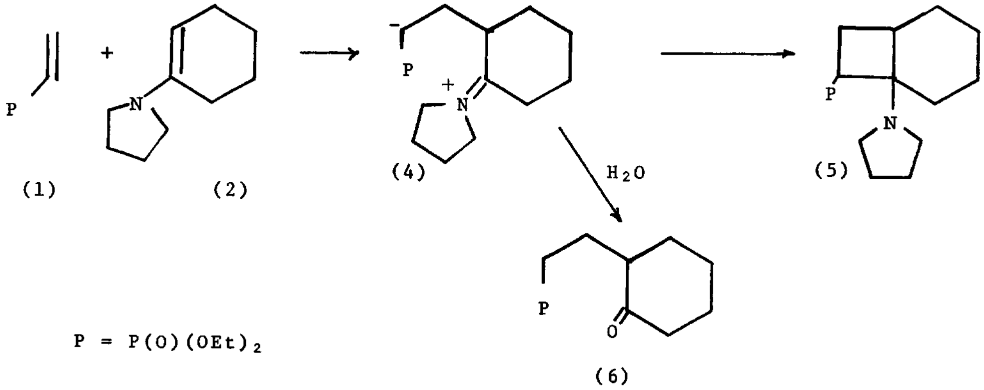
Cycloaddition reactions of enamines and electrophilic olefins have received previous attention but the reactions of alkenephosphonates have not been studied.[1] We wish to report the cycloaddition reactions of diethoxyphosphinylethene which leads to a very stable beta-aminophosphonate or a cyclobutenephosphonate.[2]

When a solution of diethoxyphosphinylethene[3] (1) and 1-pyrrolidino-2-cyclohexene (2) or 1-pyrrolidino-2-methylpropene (3) in toluene is refluxed for 90-100 hr, products corresponding to Michael addition (6) and cycloaddition (5) were obtained.

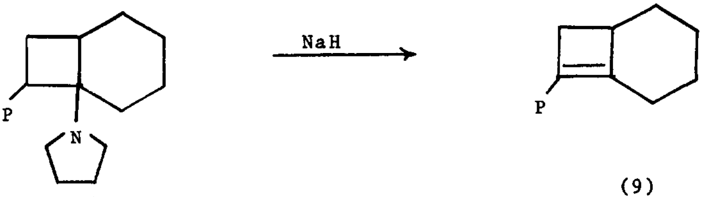


P = P(O)(OEt)$_2$

Water was added to the refluxing solution at the end of the reaction to hydrolyze imines and enamines. The respective beta-aminophosphates were isolated, upon neutralization of the aqueous acid extracts of the reaction mixture. The yields were, 1-pyrrolidino-8-diethoxyphosphinylbicyclo-[4.2.0]-octane (5) 88%, bp 150-153° (0.4 mm) and 3-diethylphosphinyl-2-pyrrolidino-3,3-dimethylcyclobutane (7) 62%, bp 133-135° (0.7 mm). The reaction between the vinylphosphonate and 1-piperidinopropene was exothermic and was, therefore, carried out at room temperature. The yield of 1-diethoxyphosphinyl-2-piperidino-3-methylcyclobutane (8) was 35%, bp 120-122° (0.3 mm).

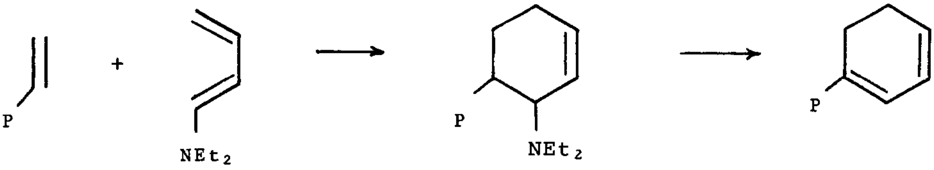
In previous enamine cycloadditions[1] evidence for the reaction sequence was not found. In accordance with a nonconcerted (2+2) reaction, the cycloaddition must be a two-step process involving a Michael addition to the vinylphosphonate to give intermediate (4) followed by a Mannich reaction to give product (5). If the reaction mixture containing 1-pyrrolidinocyclohexene is refluxed only 36 hr there is obtained a ketone, 2-(2-diethoxyphosphinylethyl)-cyclohexanone (6), 25%, 1-pyrrolidino-8-diethoxyphosphinylbicyclo[4.2.0]octane (5) 45%, and the starting vinylphosphonate (1), 25%. Uncyclized products similar to (6) were obtained in the earlier reports only upon heating the cyclo-adducts to induce a retro-Mannich reaction.[1]

The beta-aminophosphonate products did not undergo noticeable retrocycloaddition. They also did not deaminate thermally. This is surprising as a nitrogen analog of the Emmons-Wittig[4] reaction might have been expected. Hydrocarbons were not observed to be formed in these reactions. Deamination did take place when the aminophosphonates were refluxed with sodium hydride in tetrahydrofuran for 2 hr. The cyclobutenephosphonates obtained were 8-diethoxyphosphinyl-1(8)-bicyclo-[4.2.0]octene (9), 75%, bp 120-122° (0.5 mm); 1-diethoxyphosphinyl-3,3-dimethylcyclobutene (10) 56%, bp 100-100° (0.5 mm); and 1-diethoxyphosphinyl-3-methylcyclobutene (11) 51%, bp 80-83° (0.1 mm).



(5) (9)

The cycloadditions of vinylphosphonates and enamines appear quite general. For example, 1-diethylamino-1,3-butadiene (12) and (1) give 1-diethoxyphosphinyl-2-diethylamino-3-cyclohexene (13) 57%, bp 107-110° (0.15 mm). While cycloaddition reactions of the dienamine (12) have been studied before[5] the hitherto unknown reaction of the vinylphosphonate (1) again illustrates the resistance of beta-aminophosphonates to undergo Wittig elimination and the generality of the cycloaddition reaction. When the amine (13) was refluxed with methyl iodide or sodium hydride as before, deamination occurred readily to give 1-diethyl-phosphinyl-1,3-cyclohexadiene (14) 54%, bp 80-82° (0.1 mm) $\lambda_{\text{Max}}^{\text{EtOH}}$ 255 mm (ε 18.7 x 10^3).



(1) (12) (13) (14)

The beta-aminophosphonates may be considered analogs of the natural aminophosphonates.[6] At present aminophosphonates have been obtained by the Curtius[7] and Hoffman[8] degradations or a Gabriel[9] synthesis. We suggest that a suitable Mannich reaction would lead to the synthesis of aminophosphonates and would not result in the formation of olefins by a nitrogen analog of the Wittig olefin synthesis.

All compounds were characterized spectroscopically (i.e., u.v., n.m.r., mass) and by elemental analysis.

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