Available online at www.sciencedirect.com

ScienceDirect

Tetrahedron 63 (2007) 10059–10066

Tetrahedron

Reaction of unsaturated phosphonate monoesters with bromo- and iodo(bis-collidine) hexafluorophosphates

Virginie André,[a,b] Hind Lahrache,[a] Sylvie Robin[a,b] and Gérard Rousseau[a,b,*]

[a]*Univ Paris-Sud, I.C.M.M.O.,UMR8182, Laboratoire de Synthèse Organique et Méthodologie,*
Bât. 420, Orsay Cedex F-91405, France
[b]*CNRS, UMR 8182, Orsay Cedex F-91405, France*

Received 5 April 2007; revised 10 July 2007; accepted 12 July 2007
Available online 19 July 2007

Abstract—Reaction of unsaturated phosphonate monoesters with bromo- and iodo(bis-collidine) hexafluorophosphates are reported to lead to the formation of five- to seven-membered phostones by *exo* mode cyclizations. When the chains of the unsaturated phosphonate monoesters are substituted in α of the double bond by a dioxolane group *endo* mode cyclizations are observed. These cyclizations give rise to the formation of 1,2-oxaphosphepane-2-oxide and 1,2-oxaphosphocane-2-oxide.

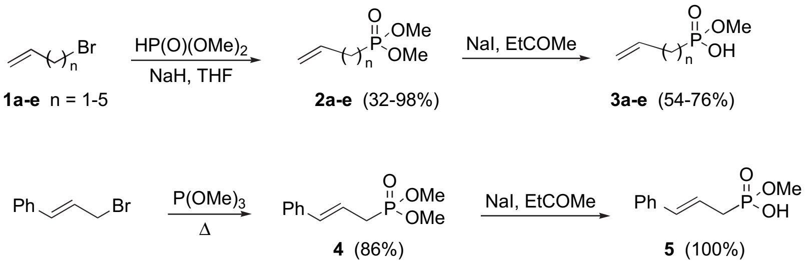
1. Introduction

We have previously reported that reaction of iodo- and bromo(bis-collidine) hexafluorophosphates with ω-ethylenic acids allowed the formation of halo lactones of various ring sizes.[1] Reactions with the corresponding phosphonates have been also examined in the literature. Maas and Hoge reported first the possibility to carry out such cyclizations.[2] They found that cyclic phosphonates could be obtained by reaction of 2-isopropenylcyclopropylphosphonates and phosphinates with bromine.[2] Zhao and co-workers reported that in the case of structurally less favored phosphonates, bromine does not react, and only the reaction with iodine was effective and led to the formation of five- and six-membered cyclic phosphonates.[3] It was subsequently reported that bromine could be also used for these cyclizations if phosphonates monoesters were used.[4] Cyclizations of allenic phosphonic acids and phosphonates into 1,2-oxaphosphol-3-enes have been also reported.[5,6]

The aim of this report is to examine the behavior of unsaturated phosphonate monoesters with iodo and bromo(bis-collidine) hexafluorophosphates, to study the scope of these cyclizations and apply them to the formation of phospho sugar derivatives. The case of α,β-ethylenic phosphonates, which lead to dephosphorylation reactions has been already reported.[7]

2. Results

The substrates studied have been prepared as reported in Scheme 1. Reaction of bromoalkenes **1a–e**[1b] with dimethylphosphite in the presence of sodium hydride in THF[8] gave rise to the formation of dimethylphosphates **2a–e** in satisfactory yields. The monohydrolysis to products **3a–e** were then carried out by reaction with 1 equiv of NaI in butan-2-one at reflux. Methyl 3-phenylallylphosphonate **5** was obtained by heating of cinnamyl bromide with trimethylphosphite,



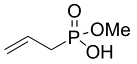
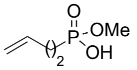
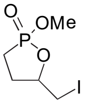
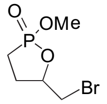
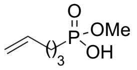
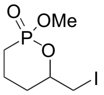
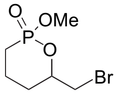
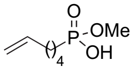
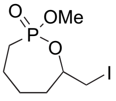
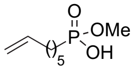
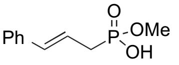
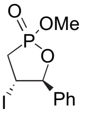
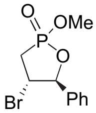
Scheme 1.

Keywords: Electrophilic cyclization; Phosphocane; Phosphepane; Heterocycle; Halo reagent.

* Corresponding author. Tel.: +33 1 69 15 78 60; fax: +33 1 69 15 62 78; e-mail: grousseau@icmo.u-psud.fr

0040–4020/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tet.2007.07.032

Table 1. Reaction of phosphonate monoesters **3a**–**e** and **5** with iodo- and bromo(bis-collidine) hexafluorophosphates

Entry	Substrate	Iodo phostone (yield, %)	Bromo phostone (yield, %)
a	 **3a**	Degradation	Degradation
b	 **3b**	 **6b** (83) 55:45[a]	 **7b** (46) 60:40[a]
c	 **3c**	 **6c** (76) 66:33[a]	 **7c** (67.5) 70:30[a]
d	 **3d**	 **6d** (64.5) 62:38[a]	See text
e	 **3e**	Degradation	Degradation
f	 **5**	 **8** (57) 65:35[a]	 **9** (44) 45:55[a]

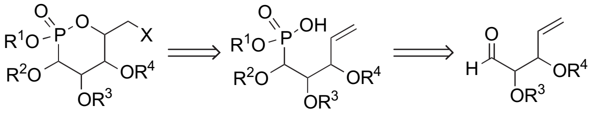
[a] Proportion of the diastereomers.

followed by monohydrolysis. The structure of products **2a**–**e**, **3a**–**e**, **4**, and **5** were determined from their NMR, IR, and mass spectra, and by comparison with the literature data when possible (see Section 4).

The reaction of compounds **3a**–**e** and **5** with 1.3 equiv of iodo- and bromo(bis-collidine) hexafluorophosphates were carried out in dichloromethane at rt. Our results are reported in Table 1.

In the case of phosphonate monoesters **3b**,**c**, we observed the formation of the corresponding iodo- and bromo phostones **6b**,**c** and **7b**,**c**, in satisfactory yields. Their structures were deduced from their spectra data and confirmed by comparison with the literature data for the known products. A mixture of two diastereomers, due to the chiral phosphorus atom, is observed in all cases. No product was obtained starting from the allylphosphonate monoester **3a**. These results are not surprising, due to the probable very low stability of the expected 1,2-oxaphosphetanes. Reaction of iodo(bis-collidine) hexafluorophosphate with the phosphonate monoester **3d** led to the iodo phostone **6d** in a satisfactory yield, while reaction of bromo(bis-collidine) hexafluorophosphate led to a complex mixture of products in which the *endo* and *exo* cyclization products could be detected. However, they could not be isolated in an enough pure state to be fully characterized. The formation of the eight-membered phostone was not observed from phosphonate **3e**. This failure, as in the case of the carboxylic acids, is probably due to the fact that higher activation energies are required for this ring size.[1] In the case of the phosphonate monoester **5**, the stable *endo* cyclization products **8** and **9** were obtained. These *endo* cyclizations were favored by the presence of the phenyl group.

We were then interested by application of these cyclizations to the preparation of phospho sugars. Different methods have been developed for their synthesis.[9] However, the possibility to obtain such derivatives by electrophilic cyclization of unsaturated phosphonates has not been yet examined. The aim of our work was thus to apply this methodology to the preparation of such derivatives according to the retro synthetic pathway indicated in Scheme 2.



Scheme 2.

Preparation of phosphonates **15** is outlined in Scheme 3. Starting from L-tartaric acid, monoprotected diol **10** was obtained using a reported procedure.[10] Swern oxidation, followed without purification of the aldehyde, by a Wittig reaction, led to the unsaturated silyl ether **11**.[11] After cleavage of the silyl ether, phosphonate **13** was then obtained as a mixture of two diastereomers in a one-pot procedure by Swern oxidation of alcohol **12** followed by addition of dimethylphosphite. These diastereomers could not be separated by liquid chromatography over silica gel. We were not able to attribute the relative stereochemistry of these diastereomers from their NMR spectra, even if in the literature the major isomer was always reported to have the *anti* stereochemistry.[12] Protection of its alcohol function as benzyl ether,[13] allowed a partial separation of the two diastereomers by liquid chromatography over silica gel. In the conditions used for this reaction, we observed a slight epimerization of the