



# STEREOSPECIFIC SYNTHESIS OF ALKENES FROM 1,2-DIOLS; MECHANISTIC VIEWS; THE ORGANIC CHEMISTRY NOTEBOOK SERIES, A DIDACTICAL APPROACH, N° 8

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## ABSTRACT

This is the eighth chapter in the series: "The Organic Chemistry Notebook Series, a Didactical Approach".

The aim of this series of studies is to help students to have a graphical view of organic synthesis reactions of diverse nature. Here we discuss, from a mechanistic stand point, some methods for the stereospecific synthesis of alkenes from 1,2-diols. One of the best ones utilizes as precursors, the cyclic thionocarbonates obtained from the diol with thiophosgene. We describe by mechanisms, the use of 1,3-dimethyl-2-phenyl-1,3,2-diazaphospholidine as an alternative for the decomposition of thionocarbonates into alkenes. We discuss by mechanisms, a general and unambiguous method for the interconversion of *Z*- and *E*-alkenes. Thus, the conversion of the (*Z*)-cyclooctene into the *E* isomer is detailed here. The mechanism of the conversion of *meso*-1,4-diphenylbutan-2,3-diol into (*Z*)-1,4-diphenyl-2-butene is here described. We have used various series of reactions reviewed by W. Carruthers in 'Some modern methods of organic synthesis', and we have proposed didactical and mechanistic views for them. This theme is included in the chapter "Formation of carbon-carbon double bonds" in the text mentioned above. *Spanish title: Síntesis estereoespecífica de alquenos a partir de 1,2-dioles; vistas mecanicísticas; de la serie: El cuaderno de notas de química orgánica, un enfoque didáctico, N°8.*

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## INTRODUCTION

During master classes of organic chemistry we noticed that students are confronted with a lack of knowledge with regard to mechanisms. For instance, oxidation-reduction reactions which are among the most commonly employed constitute a kind of black box for the student's mind. A mechanistic approach about any kind of reaction enhances the capacity of facing new reactions with respect to an understanding of all processes involved in them, and also develops synthetic creativity. As academics we feel concerned with the didactical importance of covering these needs in debutant students in organic synthesis. This, the stereospecific synthesis of alkenes from 1,2-diols, is the eighth study in: "The Organic Chemistry Notebook Series, a Didactical Approach" [1-7].

## REACTIONS AND THEIR MECHANISTIC PROPOSALS, DISCUSSION

The synthesis, regioselective and stereospecific of double bonds, is feasible from 1,2-diols [8]. All procedures include the formation of an intermediate of the type **1** (Fig. 1), which decomposes into products [8]. One of the best of the various methods available uses the cyclic thionocarbonates **3**, (Fig. 1) [8]. These are obtained from reaction of the diol with thiophosgene, Fig. 1 [8]. The fragmentation started with the thionocarbonates transformed into alkenes by heating with triethylphosphate; more recently, the conversion is done only at 25-40 °C by using thionocarbonate with

1,3-dimethyl-2-phenyl-1,3,2-diazaphospholidine [8,9]. It is believed a concerted process or a process that includes an intermediate carbene (2) [8].

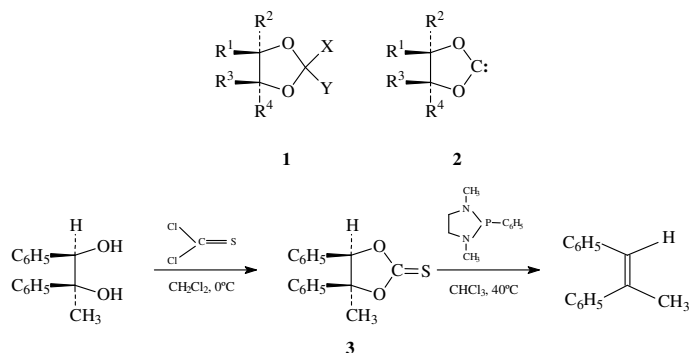


Figure 1. Synthesis, regiospecific and stereospecific of double bonds; feasible from 1,2-diols; reviewed by W. Carruthers [8]

The mechanistic approach to the reactions appearing in Fig. 1, are exposed in Fig. 2.

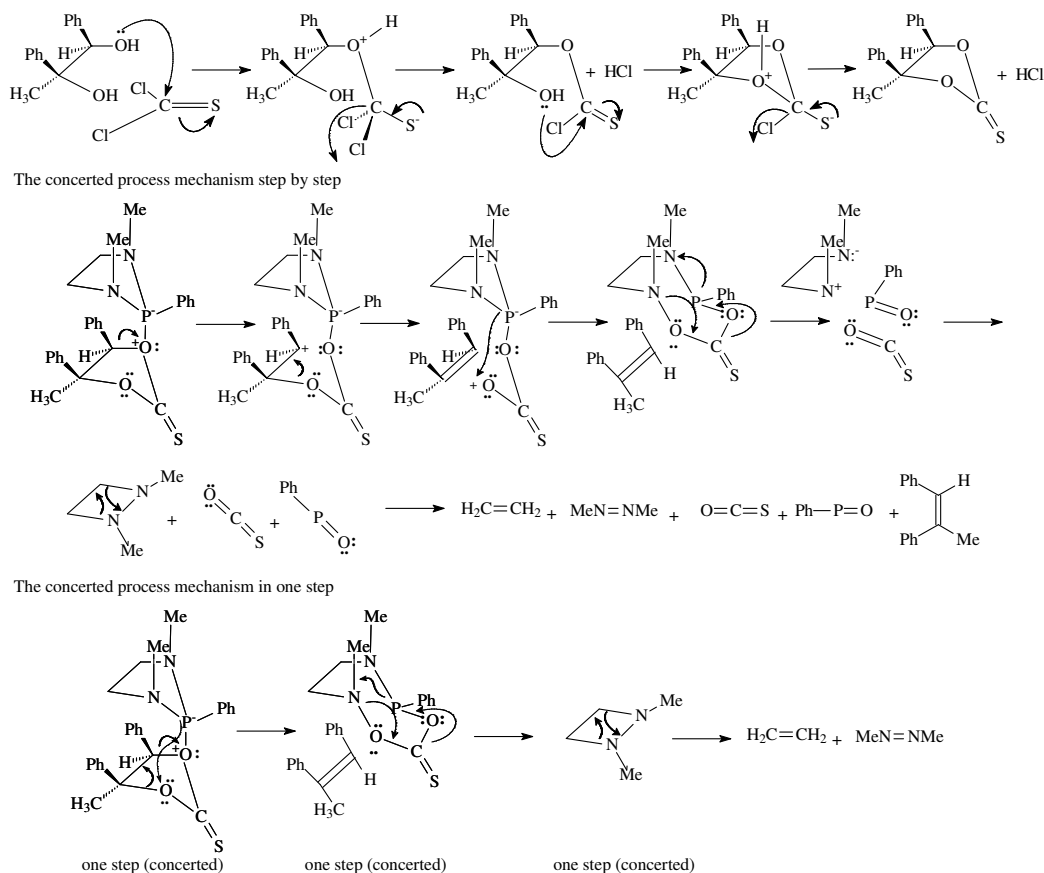


Figure 2. Synthesis, regiospecific and stereospecific of double bonds; feasible from 1,2-diols; mechanistic proposal

#### Comments

In Figure 2, a nucleophilic attack from the oxygen of the diol over the carbon of the analogue-of-carbonyl C=S, is shown in the first step. The protonated ether formed eliminates a HCl to afford an analogue of a thioester, the S=C-O (with the bond 'pi' shared between O and S [S-C=O ↔ S=C-O]). The carbon of C=S (analogue-of-carbonyl) suffers a new nucleophilic attack, this time from the other hydroxylic oxygen to replace another chloride that correlates with

the liberated  $H^+$  from the just formed ether linkage (second HCl). Now, both oxygens are activated by the thionocarbonate toward elimination. However the process takes place only due to the catalysis-type action of the 1,3-dimethyl-2-phenyl-1,3,2-diazophospholidine. The term “concerted mechanism” implies an only step when all excision-formation of bonds occur simultaneously. It is also implied the absence of ions, however with didactical purposes we explain the concerted mechanism (an only step) in three derived steps that include precisely ions. Besides the alkene, the residue is an eight-membered polyheterocycle. Also, we propose a disintegration of this cycle that occurs in one concerted step, in three didactical steps. The resulting four-membered diazocycle, disintegrate in a concerted way. The final products are: the alkene pursued, ethylene, azomethane [10], carbonyl sulfide [11], and  $PhP=O$ .

Given the mild conditions, the reaction can be used in the synthesis of complex molecules and sensitive due to the presence of many functional groups [8]. As an example, the 3,5-acetonide of the complex macrolide named as erythronolide A, can be transformed into the 11,12-deoxy derivative; hence, the diol **4** gives **5**, with a yield of 75 % [8]. The reactions proceed by keeping stereospecificity following a *syn* elimination route [8]. This is an excellent method to produce cycloalkenes suffering strain due to 1,2-substituents mutually hindered [8]; see Fig. 3. This method and the *trans* perhydroxylation [12] constitute the virtuous cycle for the isomerization between *Z*- and *E*-alkenes [8]. Figure 4 shows the corresponding mechanisms.

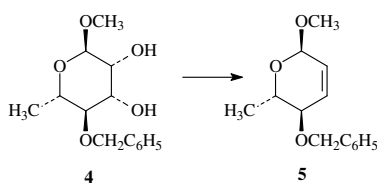


Figure 3. Synthesis of 11,12-deoxyerythronolide A; reviewed by W. Carruthers [8]

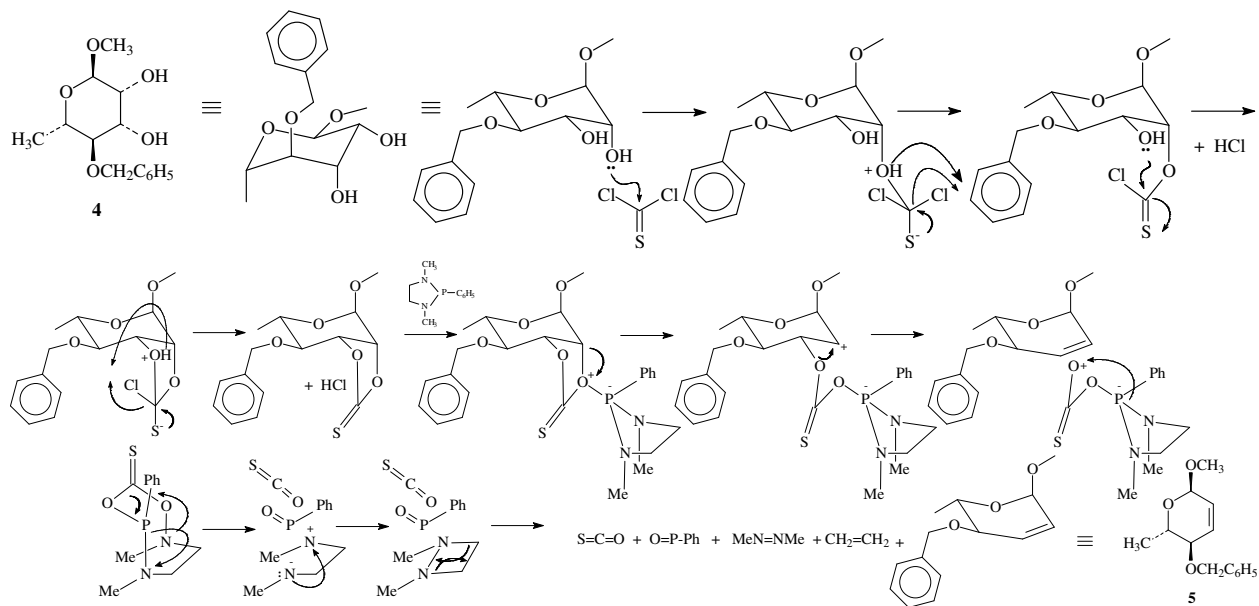


Figure 4. Synthesis of 11,12-deoxyerythronolide A; mechanistic views

#### Comments

The same remarks done for Fig. 2 are applicable for Fig. 4.

Other examples are the conversion of *meso*-1,4-diphenylbutan-2,3-diol into (*Z*)-1,4-diphenyl-2-butene [8], and the synthesis of its *E*-isomer starting from the *dl*-1,4-diphenylbutan-2,3-diol [8]. The mechanistic development of these transformations is pictured in Fig. 5 and 6 respectively.

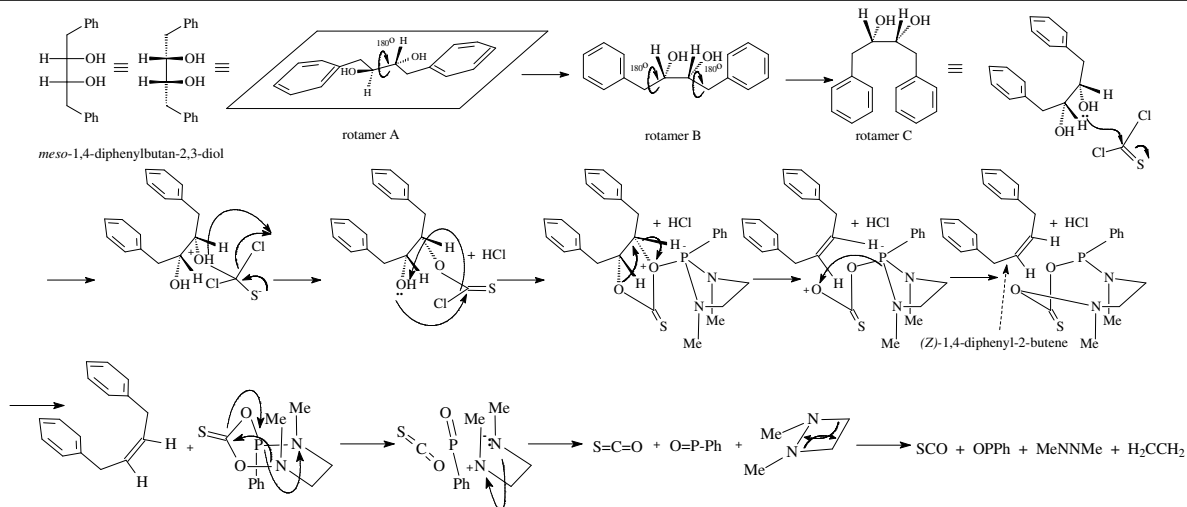


Figure 5. Synthesis of (Z)-1,4-diphenyl-2-butene from meso-1,4-diphenylbutan-2,3-diol; mechanistic view

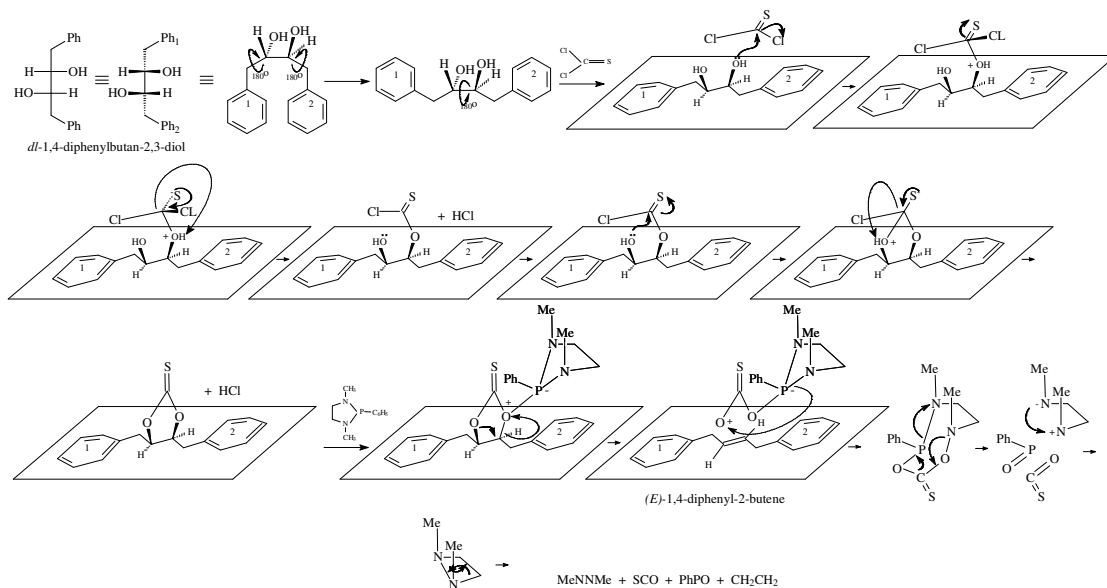


Figure 6. Synthesis of (E)-1,4-diphenyl-2-butene from dl-1,4-diphenylbutan-2,3-diol; mechanistic view

Figure 7 represents the isomerization Z→E of (Z)-cyclooctene as reviewed by W. Carruthers [8].

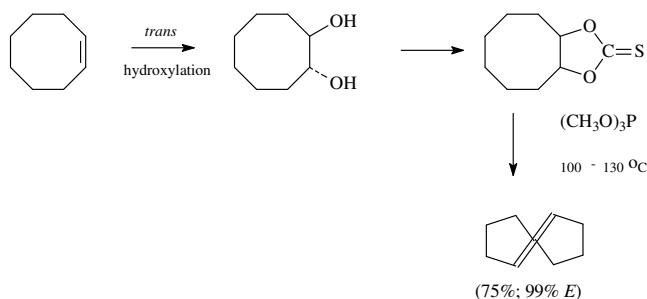


Figure 7. Conversion of (Z)-cyclooctene into its E-isomer; reviewed by W. Carruthers [8]

Figure 8 shows mechanistically how (*Z*)-cyclooctene can be converted in its *E*-isomer [8], following a similar protocol to the one used previously in this discussion. Alternatively, another derivative of 1,2-diol, the benzylidene, can be treated with butyl-lithium [8]. This method is however of limited application, given the high susceptibility of many functional groups toward the butyl lithium [8]. The method is suitable with lightly substituted alkenes only [8,13]. Other methods with stereospecificity include acetals derived from the diol with ethyl-orthoformate [8,14], or *N,N*-dimethylformamide dimethyl acetal [8,15].

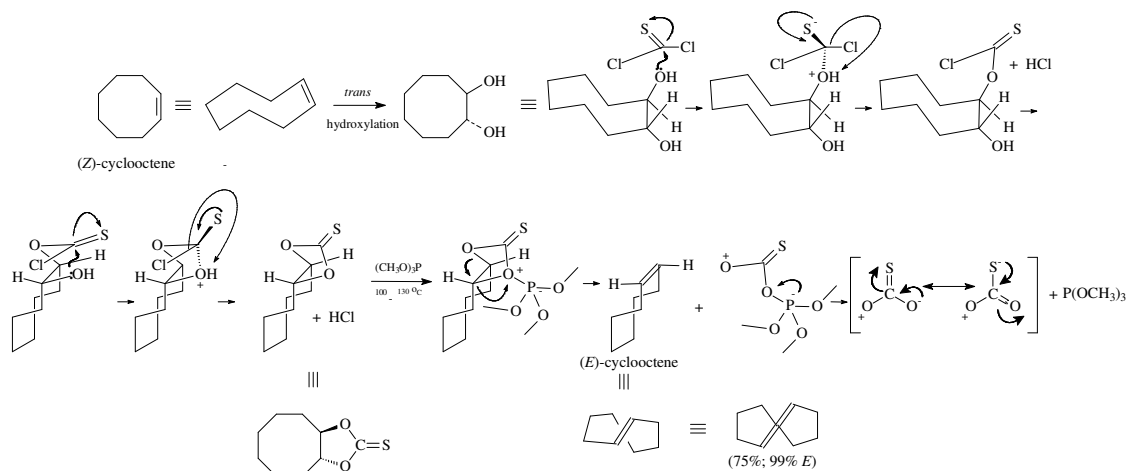


Figure 8. Conversion of (*Z*)-cyclooctene into its *E*-isomer; mechanistic view

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