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ALPHA-DEUTERIUM ISOTOPE EFFECTS IN THE THERMOLYSIS OF ß-HYDROXY ESTERS

Jairo Quijano

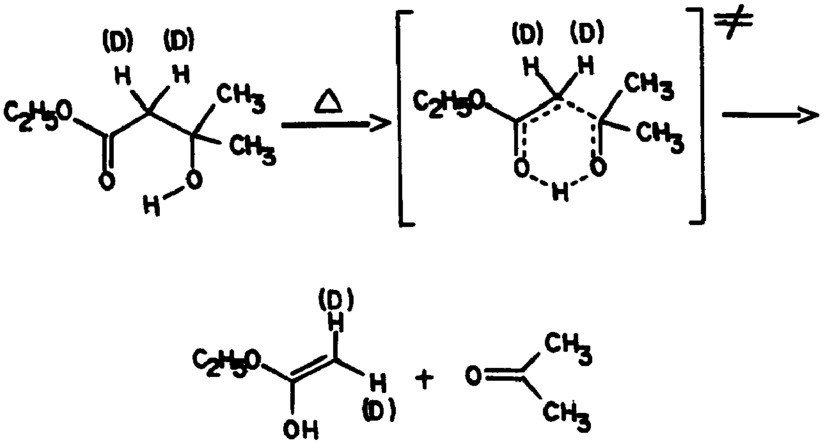
Departamento de Química - Universidad Nacional de
Colombia, Apartado Aéreo 568 - Medellín - Colombia

Iliana Restrepo , Luis H. Gallego , M. del Socorro Yepes

¨ Departamento de Química - Universidad de Antioquia -
Apartado Aéreo 1226 - Medellín - Colombia

Abstract: Alpha secondary isotope effects are determined experimentally by thermolysis of ß-hydroxy esters. These results are compatible with a change of hybridization of carbon-2 from reactant to transition state (sp^3 - sp^2).

In a previous paper,[1,2] we showed that ß-hydroxy esters may be pyrolyzed to mixtures of aldehydes, or ketones and the corresponding ester. A cyclic six-membered transition state was proposed based on the products, kinetics and activation parameters of the reaction.



Recently,[3] we studied the primary and ß-cumulative secondary isotope effects in order to evaluate the validity of this mechanism. The small value of the primary isotope effect suggests that the transfer of hydrogen, partially bonded to the oxygens of the carbonyl and hydroxyl groups in the transition state, is not linear, or the transition state is either early or late.

As a complement to these studies, we present the kinetics of pyrolysis of ethyl-2,2-d$_2$-3-hydroxy-3-methyl butanoate and ethyl-3-hydroxy-3-methyl butanoate (Table I).

Table I
Rate constants and Kinetic Isotope Effects of Pyrolysis of ß-Hydroxy esters (206 ± 0,5 °C)

ß-hydroxyesters	10^6 k (s^{-1})	k_H/k_{D2}
Ethyl-3-hydroxy-3-methyl butanoate	2.76 ± 0.08	1.26 ± 0.06
Ethyl-2,2-d$_2$-3-hydroxy-3-methyl butanoate	2.19 ± 0.08	

Each reaction was followed to at least three half-lives. Good first-order kinetics were observed; the first order plots were linear for the period during which the reaction was followed.

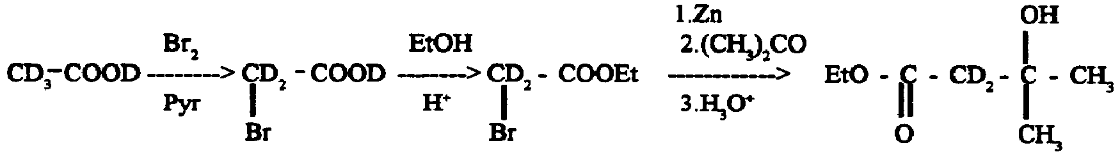
The results shown in Table I are in agreement with the proposed transition state. In this mechanism we postulated that the carbon-2 changes its hybridization from $sp^3 \rightarrow sp^2$.

According to the Streitwieser model,[4] the alpha isotope effect is due predominantly to the change of a tetrahedral C-H bending vibration to an "out-of-plane" deformation in the transition state.

Since the most important factor involved in the α-deuterium isotope effect is the isotope inhibition of the out-of-plane bending vibration, we conclude that in this reaction there is a change of hybridization of carbon-2 between reactants and transition state (sp^3 - sp^2).

The values of equilibrium isotope effects reported for pericyclic reactions vary considerably. Thus Humski et. al. [7] reported a value of 1.22 for the sigmatropic rearrangement of 3,3,4,4-tetradeuterio-1,5-hexadiene at 200°C (presumably corresponding to a value $(1.22)^{1/2} = 1.1$ for di-deuterium substitution) whereas Gajewski and Conrad [8] reported a value of 1.27 at 160°C for the Claisen rearrangement of 1,1-dideuterioallyl acetate (corresponding to 1.24 at 200°C) and the value of 1.225 at 185°C for the rearrangement of 1,1-dideuterioallyl phenyl ether (corresponding to 1.24 at 200°C). Furthermore theoretical calculations of such reactions are of the order of 1.3 (refer to Shiner,[9] and McMichael,[10]). Our kinetic isotope effect of 1.26 ± 0.06 is therefore consistent with the theoretical calculations,[9,10] and with two of the three earlier sets of experimental results [7]. As pointed out by Hartson and Shiner,[9] the inconsistency of the experimental results in reference 7 with their calculations may be due to the uncertainty in the experimental results. The value that we have observed seems to be a large one and suggests a late transition state.

ß-Hydroxy esters were obtained by the Reformatsky reaction,[5] and deuterated compound by the following sequences of reactions [6]:



$$CD_3\text{-}COOD \xrightarrow[Pyr]{Br_2} \underset{|\atop Br}{CD_2}\text{-}COOD \xrightarrow[H^+]{EtOH} \underset{|\atop Br}{CD_2}\text{-}COOEt \xrightarrow[3.H_3O^+]{\substack{1.Zn\\2.(CH_3)_2CO}} EtO\text{-}\underset{\|\atop O}{C}\text{-}CD_2\text{-}\overset{OH\atop |}{\underset{|\atop CH_3}{C}}\text{-}CH_3$$

The kinetic method used was described previously. [1,3] The amount of acetone and ethyl acetate produced was determined by glc.

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