Tetrahedron Letters No. 44, pp 4413 - 4416, 1973. Pergamon Press. Printed in Great Britain.

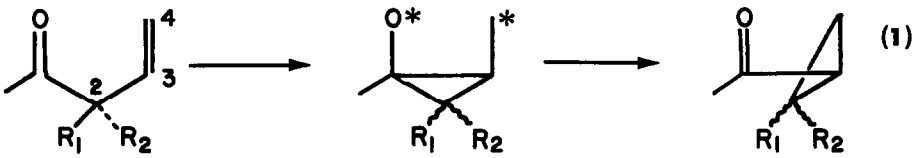
THE STEREOCHEMISTRY OF THE OXA-DI-π-METHANE REARRANGEMENT

Jeffrey I. Seeman and Herman Ziffer*

National Institute of Arthritis, Metabolism, and Digestive Diseases
National Institutes of Health, Bethesda, Maryland 20014

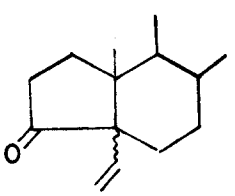
(Received in USA 30 July 1973; received in UK for publication 25 September 1973)

The photochemical isomerization of a β,γ-unsaturated ketone to a cyclopropyl ketone,[1-3] labeled an oxa-di-π-methane rearrangement by Dauben,[1] has been observed in a wide variety of compounds (see eq. 1). We now report results which (1) indicate that the rearrangement can be highly stereospecific; (2) reveal the stereochemical consequences about C-2 in the process; and (3) support either a concerted $\sigma^2s + \pi^2s$ process or a stepwise mechanism in which initial 1,3-bonding determines the stereochemistry of the product.



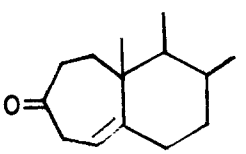
(1)

For our study, compounds 1a,b were prepared from the direct irradiation of the A-homocholestenone 2.[4] The photolysis of 1a and 1b in acetone with a 450 watt Hanovia high pressure lamp through Pyrex led to a single photoproduct in each case. The photoproducts from 1a and 1b were demonstrated to be 3b and 3a respectively by a comparison of the physical and spectral properties with those of the known compounds.[5]

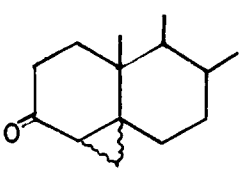


1

a: 5α-vinyl
b: 5β-vinyl



2



3

a: 4α, 5α-methano
b: 4β, 5β-methano

The observation that 1a and 1b each lead to a different product excludes the possibility of a common intermediate in the rearrangement (e.g. α-cleavage and subsequent bond formation). In addition, the absence of photoepimerization at C-5 in 1a and 1b proves that triplet α-cleavage to a long lived diradical does not occur.

The oxa-di-π-methane rearrangement may be analyzed as a concerted cycloaddition and two pathways are allowed, $\sigma^2s + \pi^2s$ and $\sigma^2a + \pi^2a$.[6] One stereochemical consequence of a $\sigma^2a + \pi^2a$ Process is inversion about C-2 (see eq. 1) whereas a $\sigma^2s + \pi^2s$ process required retention at C-2. Although the stereochemical pathway for this isomerization has been labeled $\sigma^2a + \pi^2a$ in a number of cases,[2,7] in each of these the starting material was forced by steric constraints to adopt this mode of reactivity.[2,7] Since the double bond in 1 is acyclic, both π^2s and π^2a modes of addition are geometrically permitted. Because the photoproducts from 1a and 1b each form with retention at C-5 (C-2 in eq. 1), the oxa-di-π-methane rearrangement of 1, if concerted, must be a $\sigma^2s + \pi^2s$ process.

The reaction of 1b → 3a could also occur via a stepwise mechanism in which initial carbonyl-vinyl bonding leads to two species, 4a and 4b (see eq. 2). Species 4a or 4b can then proceed directly (path C) or via a second intermediate 5a or 5b (path B) to 3a or 3b respectively. An analogous discussion can be made for the isomerization of 1a → 3b. The specificity of the isomerizations of 1a and 1b require either a highly stereoselective initial bond formation in 1b to lead preponderately to 4a or requires any 4b formed from 1b to revert to starting material (Path A) and not continue to product. Stereospecificity in the initial bonding process can be rationalized on the basis of 1,3-bonding in the preferred conformations of 1 in which the vinyl group is directed away from the steroid nucleus

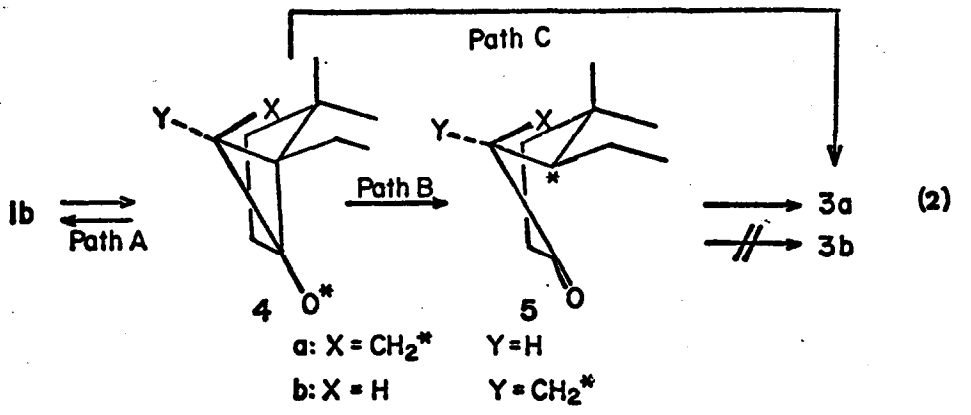
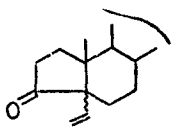
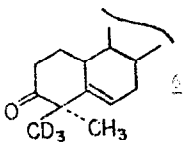
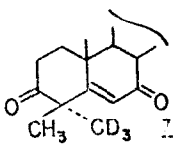
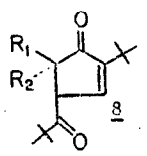


TABLE I

Compound	Refs.	Sterically Permitted Concerted Modes	Results Consistent With:	Oxa-di-π-Methane Mechanism (See eq. 2)
	This Work	$\sigma^2_s + \pi^2_s$ $\sigma^2_a + \pi^2_a$	$\sigma^2_s + \pi^2_s$	Path B with stereospecific 1,3-bonding to product or Path C with partitioning (see text)
	8a,b	$\sigma^2_a + \pi^2_a$	Non-concerted or $\sigma^2_a + \pi^2_a$ followed by product isomerization	Incomplete reaction information[8a,c]
	9	$\sigma^2_a + \pi^2_a$	Non-concerted or $\sigma^2_a + \pi^2_a$ followed by product isomerization	Incomplete reaction information[8a,c]
	10	$\sigma^2_s + \pi^2_s$ $\sigma^2_a + \pi^2_a$	$\sigma^2_a + \pi^2_a$	Path B with stereospecific final cyclopropane bond formation or Path C

The stereochemistry of the 1,2-acyl shift has been studied in three other systems, 6[8a,b], 7[9] and 8[10] and these results are summarized in Table I. The nonstereospecificity found in the rearrangements of 6 and 7 could result from the secondary isomerizations of the photoproducts as suggested by Nakanishi.[8a,c] Cyclopropyl ketones 3a and 3b do not interconvert upon acetone sensitization. This may be due to the poor orbital overlap of the internal cyclopropane bond with the carbonyl group.[8d,e]

The alicyclic nature of the double bond in 1a,b probably decreases the efficiency of the isomerization since cis-trans isomerization can compete with rearrangement as a mode of deactivation. The failure to see the oxa-di-π-methane rearrangement in other β,γ-unsaturated ketones has been ascribed to this free rotor effect.[11] However, the observation of products 3a and 3b indicates that this effect does not necessarily prohibit the reaction.[12]

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12. The same conclusion is obtained when one considers the results in reference 1.