Photoisomerization of Hindered Poly-cis Isomers of Retinal. Regioselectivity And One-Photon-Multiple-Bond Isomerization.#

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Abstract. Direct irradiation of five dicis (7,9, 7,11, 7,13, 9,11 and 9,13) and one tricis (7,9,11) isomers of retinal led to regioselective isomerization at the 13,14 bond as well as multiple-bond isomerization.

Previous studies on the photoisomerization of retinal isomers emphasize the use of the all-trans and more readily available mono-cis isomers (9-cis, 11-cis and 13cis).¹ Recent completion of the syntheses of all sixteen possible geometric isomers of retinal² allows us to investigate the photochemistry of other poly-cis isomers. In this paper, we report results on several hindered isomers, which exhibit unusual regioselectivity and one-photon-multiple-bond isomerization.

The retinal isomers used in this study included five containing the dicis geometry (7,9, 7,11, 7,13, 9,11, and 9,13), and one with a tricis geometry (7,9,11). Regioselectivity in photoisomerization was examined by determining the distribution of initial products during early stages (from 2 to 6% conversion) of direct irradiation of these isomers in hexane solution. Hplc was employed for analyses, and products



[#]Photochemistry of polyenes 27. For previous paper in the series see: X. Y. Li, A. E. Asato & R. S. H. Liu, Tetrahedron Lett., <u>31</u>, 4841 (1990).

were characterized by their ¹H-nmr spectra, comparison of retention times of authentic samples or in cases of the thermally labile isomers by on-line recording on a diode array detector of their characteristically blue-shifted uv-vis spectra.³ The cases of 7,9,11-tricis (Figure 1a) and 7,9-dicis (1b) are shown as representative examples.



Figure 1a. Hplc chromatograms (solvent: 6% diethyl ether in hexane) for product analysis from direct irradiation of 7,9,11-tricis retinal with detecting beam set at 287 (lower) and 360 nm (upper). The insert is the uv-vis absorption spectrum corresponding to the isomer with the shortest retention time, recorded on a diode-array detector. It agrees with that of all-cis retinal (see text).



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Figure 1b. Product isomer distribution during early stages of direct irradiation of 7,9-dicis retinal in hexane, determined by hplc analyses (360nm detecting beam; data corrected for different absorptivities of isomers²).

Results for all six isomers are summarized in Table 1. The following observations are evident. First, in contrast to the photochemical properties of the alltrans and mono-cis isomers,¹ the dicis isomers gave substantial amounts of two-bond isomerized⁴ primary photoproducts. Such products appear to be favored when the hindered 11-cis geometry is present or when two cis linkages are adjacent to each other (83% for 7,9-dicis and only 18% for 7,13-dicis). Three-bond isomerized products were also detected from some of the dicis isomers (appeared to be favored under degassed conditions, i.e., in the absence of a triplet quencher) and in particular from the 7,9,11-tricis isomer where even a small amount of the four-bond isomerized product (13-cis) was also detected. That these products are not due to two photon excitation was revealed by the insensitivity of the ratio of multiple-bond to one-bond isomerized products upon a 64 fold variation of light intensity (entries 14-17).

While formation of the two-bond isomerized products are consistent with involvement of the bicycle pedal mechanism,⁵ we do not believe the current result demands postulation of such a concerted process. In fact, considering the known high triplet yield of retinal isomers in non-polar solvents (approx. 0.5)^{1a} and preference for such processes under conditions favored for triplet processes, we are inclined to believe that a mechanistic pathway involving cascade of isomeric triplets with the initial loss of the sterically crowded 11-cis or 7-cis geometry is more likely.

Table 1. Photoisomerization of poly-cis isomers of retinal

in hexane: initial product distribution^a

Entry	Isomer	Conditions	Initial products (% among all products)
1	7,9c	aerated	13c(2); 9c(5); 7,9,13c(11); t(83)
2	••	deoxygenated	13c(17); 9c(5); 7.9.13c(8); t(69)
3	7.11c	aerated	11c(2); $7c(5)$; $7.11.13c(42)$; $t(51)$
4	**	deoxygenated	11c(3); 7c(3); 7, 11, 13c(51); t(43)
5	7,13c	aerated	13c(23); 7c(69); t(8)
6	**	deoxygenated	13c(15); 7c(67); t(19)
7	9.11c	aerated	11c(-); 9c(10); 9, 13c(5); 9, 11, 13c(39); t(45)
8		deoxygenated	13c(7); 11c(-); 9c(12); 9, 13c(7); 9, 11, 13c(36); t(38)
9	9.13c	aerated ^b	13c(17); 9c(72); t(10)
10	**	deoxygenated	13c(10); 9c(70); t(21)
11	7.9.11c	aerated	7.9c(4); all-c(61); 9c(3); 7.9.13c(1); $t(31)$; 13c(-)
12		deoxygenated	7.9c(4); all-c(62); 9c(3); 7.9.13c(1); $t(25)$; 13c(5)
13	**	sensitized	7.9c(-); all-c(-); 9c(4); 7.9.13c(-); $t(90)$; 13c(7)
14	7.9c	aerated.88cm ^C	13c(-); $9c(3)$; 7.9.13(10); t(86)
15		aerated.llcm ^C	13c(-); $9c(3)$; 7.9, $13(12)$; $t(85)$
16	7.9.11c	aerated.88cm ^C	7.9 $c(4)$; all- $c(58)$; 9 $c(2)$; 7.9.13 $c(2)$; t(34)
17		aerated, llcm ^C	7,9c(3); all-c(60); 9c(2); 7,9,13c(1); t(33)

a. $\sim 1 \times 10^{-4}$ M, 365 ± 4nm with monochromator or 366nm band with 0-52, 7-60 filter plates, 24°C, 2-6% conversion. Deoxygenated samples: argon saturated. Sensitized: 5 cycles of free-pump-thaw, then sealing under vacuum. b. Waddell et al. reported at 350nm and $\sim 25\%$ conversion: 13c(49); 9c(49) and t(2). c. Distance from focal point of condensed beam.

To confirm possible participation of the triplet state in the multiple-bond isomerization process, we carried out porphyrin sensitized¹c isomerization of the 7,9,11-tricis isomer (entries 13). The altered product composition suggests in this case little involvement of the triplets in the isomerization process during direct irradiation. Also, the multiple-bond isomerized products are indeed more favored (90%) under sensitized than in direct irradiation (25-31%). It should be noted that possible involvement of triplets was recently invoked to account for the quantum chain process observed in 7-cis and 11-cis-retinal.⁶ Time resolved spectroscopic studies of these retinal triplets, as were done with the all-trans and the mono-cis isomers,⁷ could clarify the exact pathway for the multiple-bond isomerization process.

For one-bond isomerized products, the most favored position of isomerization appeared to be the 13,14 bond (51% of 7,11,13-tricis from 7,11-dicis and 67% of 7-cis from 7,13-dicis). While consistent with that of the all-trans isomer,¹ the result is somewhat surprising when one considers the fact that the hindered 11-cis isomer was reported to give exclusively the all-trans isomer.⁸ One might expect that these hindered polycis isomer would similarly prefer to lose first the hindered 7-cis or the 11-cis geometry. Instead, isomerization at the unhindered 13,14-bond is preferred. To test the generality of this observation and its synthetic value, we irradiated 7,9,11tricis retinal.^{2c,8} Indeed, among the initial products, we found that the novel all-cis isomer was the major product (~60%) with the three-bond isomerized all-trans isomer being the second (~31%). Since the all-cis isomer is known to have a much blueshifted absorption spectrum,^{2b} secondary photochemical reactions could be minimized by employing a long wavelength cut-off filter. Therefore, when carried to >90% conversion with light >350nm (Corning 0-52 filter), this highly strained isomer was found to be present in 46%. We have also reinvestigated the direct irradiation of 11cis retinal. Instead of the earlier reported regiospecific isomerization to the all-trans isomer,⁹ we found that the unstable 11,13-dicis and the all-trans isomers were formed in a ratio of 1 : 2. The blue-shifted absorption spectrum and low thermal stability of the 11,13-dicis isomer perhaps complicated earlier studies.

Investigation of other poly-cis isomers, including those with the unstable 11,13dicis geometry,^{2c} are currently in progress in our laboratories.

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