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CONTROL OF THE STEREOCHEMISTRY OF 2,5-CYCLOHEXADIENONE PHOTOISOMERIZATION BY STERIC FACTORS

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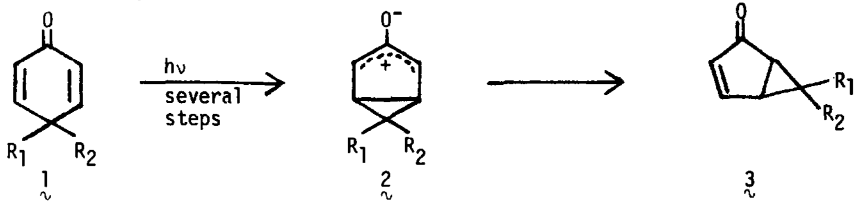
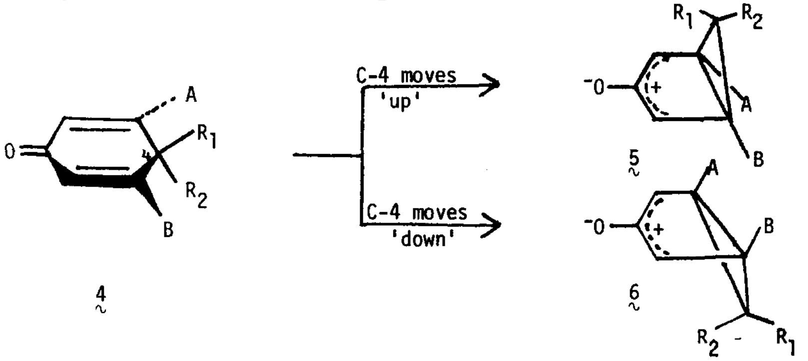
It is well established that the dipolar ion 2 is an intermediate in the photoisomerization of 2,5-cyclohexadienones 1 to bicyclo[3.1.0]hexenones 3.[1-3] The stereochemistry (that is, the



exo or *endo* disposition of R_1 and R_2) of 3, the product which is isolated, is fixed the moment a bond forms between C-3 and C-5 in 1, because it has been shown by several groups[4-7] that in cyclopropylcarbinyl rearrangements of the type represented by 2 → 3, the substituents attached to the migrating atom maintain their relative positions (that is, if R_1 is *endo* in 2, it will be *endo* in 3).

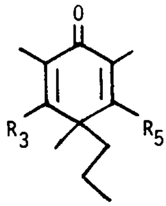
The conversion of 1 to 2 proceeds from a nearly planar geometry[8] to that of the fused bicyclo[3.1.0] ring system. During this process,[9] C-4 can move either 'up' or 'down'. If it moves 'up', placing R_1 *endo*, then at some stage R_2 must pass by groups A and B on C-3 and C-5.



The converse holds if C-4 moves 'down'. When repulsions between R_1 and/or R_2 on C-4 and A and/or B are significant, one predicts that if R_1 is larger than R_2, the product with R_1 *endo* will predominate.[10]

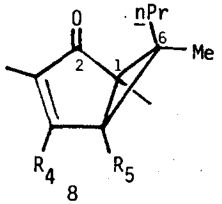
The literature holds some support for this notion. If A = B = hydrogen and $R_1 \neq R_2$, the ratio of the two stereoisomeric bicyclo[3.1.0]hexenones is close to 1.[12] If one of the groups on C-4 is particularly large (say *t*-butyl[13] or trichloromethyl[14]) relative to the other (say methyl or methoxyl) the stereoisomer with the large group *endo* may predominate in the product. Finally, in an example where A = *t*-butyl, B = H and R_1 = allyl, R_2 = H, the product has the large group (allyl) *endo*, in accord with our proposal.[15]

To test our proposal systematically, we synthesized and irradiated dienones **7a-c**. Each was prepared by alkylation of the appropriate polymethylphenoxide with allyl bromide, rearrangement of the resulting 6-allyl-6-methyl-2,4-cyclohexadienone(s) with $BF_3 \cdot Et_2O$ to the 4-allyl-4-methyl-2,5-cyclohexadienone and hydrogenation over 5% Rh/C to the corresponding propyl compound.[16]



7a $R_3 = R_5 = H$
7b $R_3 = CH_3$, $R_5 = H$
7c $R_3 = R_5 = CH_3$

Irradiations of 5-7.5% solutions of **7a-c** in methanol were performed in quartz vessels using a Rayonet apparatus with 2537 Å lamps. Reactions were followed by vpc and were complete in 1.5 - 3 hours. The reactions gave bicyclo[3.1.0]hexenones cleanly with only traces (< 5%) of minor products. The bicyclic ketones were separated by vpc and identified spectroscopically (ir, uv, nmr). The structures of isomeric pairs were readily distinguished by their nmr spectra.[17] The results are summarized as follows:



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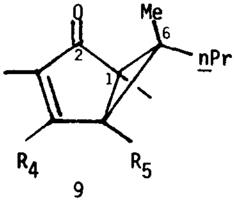

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a $R_4 = R_5 = H$

b $R_4 = CH_3$, $R_5 = H$

c $R_4 = R_5 = CH_3$

7a $\longrightarrow$ 8a (44%) + 9a (56%)

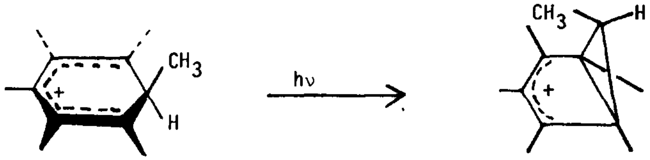
7b $\longrightarrow$ 8b (68%) + 9b (32%)

7c $\longrightarrow$ 8c (91%) + 9c (9%)

The increase in yield of the product with the larger (propyl) group endo as hydrogens at C-3 and C-5 in 7 are successively replaced by methyls is consistent with our postulate that the stereochemistry can be controlled by steric factors.

In the isomerization of 7b, none of the alternative bicyclic ketones (8 and 9 with R_4 = H, R_5 = CH_3) were isolated or produced (an nmr of the crude photoproduct showed no vinyl protons). The factors which control this specificity remain to be elucidated.[18]

Finally, the steric factors to which we have alluded may be important in other photoisomerizations. For example, they rationalize why the only isomer produced on irradiation of benzenonium ion 10 is ion 11.[6,19]



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1. H. E. Zimmerman and D. I. Schuster, J. Am. Chem. Soc., 84, 4527 (1962).

2. P. J. Kropp in "Organic Photochemistry-Volume 1" edited by O. L. Chapman, Marcel Dekker, Inc., New York, 1967.

3. D. I. Schuster and V. Y. Abraitys, Chem. Commun., 419 (1969).

4. H. E. Zimmerman and D. S. Crumrine, J. Am. Chem. Soc., 90, 5612 (1968).

5. T. M. Brennan and R. K. Hill, ibid., 90, 5614 (1968).

6. R. F. Childs and S. Winstein, ibid., 90, 7146 (1968).

7. H. Hart, T. R. Rodgers and J. Griffiths, ibid., 91, 754 (1969).

8. 1,4-Cyclohexadiene appears to be a somewhat flattened boat (see D. J. Atkinson and M. J. Perkins, Tetrahedron Lett., 2335 (1969) and references given there). With an additional sp^2 carbon, 2,5-cyclohexadienones should be even closer to planar.

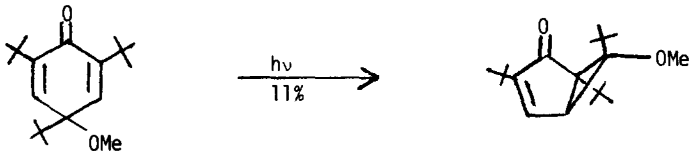
9. To conserve space, only one enantiomer of 4 is shown. The same argument applies to its mirror image.

10. Clearly other factors, one of which is solvation,[11] can also influence the stereochemical outcome.

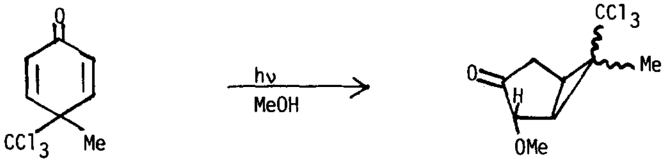
11. W. V. Curran and D. I. Schuster, Chem. Commun., 699 (1968).

12. For example, see H. E. Zimmerman and J. O. Grunewald, J. Am. Chem. Soc., 89, 5163 (1967); B. Miller and H. Margulies, ibid., 89, 1678 (1967); also, ref. 11.

13. T. Matsuura, Bull. Chem. Soc. Jap., 37, 564 (1964) reported that



14. The authors of ref. 3 reported that



Only one isomer was obtained. The relative positions of the methyl and CCl_3 groups is not yet known; we would predict CCl_3 endo.

15. B. Miller, J. Am. Chem. Soc., 89, 1690 (1967); the paper contains three other examples which, though not as clear-cut because the starting material was not a 2,5-cyclohexadienone, nevertheless are in accord with our proposal. In these examples, A = methyl, B = H, R_1 = allyl, n-propyl or trans-2-butenyl and R_2 = H. In all products, R_1 is endo.

16. All new compounds gave correct elemental analyses and spectra consistent with the assigned structures.

17. For example, the C-6 methyl in 8a-c is a singlet at τ 8.85, 8.87 and 8.93 respectively, whereas in 9a-c, this methyl appears at τ 9.08, 9.15 and 9.13. Shielding of the 6-endo methyl in such compounds is well established (see H. Hart and D. W. Swatton. J. Am. Chem. Soc., 89, 1874 (1967)). Complimentary shifts were observed in the propyl multiplets.

18. In other examples where such discrimination is possible (see, for instance, ref. 15) the reactions were also specific, though the product was the less substituted alkene.

19. V. A. Koptyug, L. I. Juzubova, I. S. Isaev and V. I. Mamatyuk, Chem. Commun., 389 (1969); see also R. Criegee and H. Grüner, Angew. Chem. Int. Ed., 7, 467 (1968).