EPIMERIZATION OF 2,4-DIBENZILIDENE-6-METHYLBICYCLO(3.1.0)HEXAN-3-ONE

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Abstract Thermal epimerization of the title compound occurs readily at > 150°C, with Eyring parameters of $\Delta H^{\ddagger} = 29.8$ kcal/mol and $\Delta S^{\ddagger} = -10.8$ cal/mol-K, consistent with a planarized intermediate or transition state

The pentamethylenepropane (PMP) diradical system 1 has been of interest since it was identified by Borden and Davidson as being structurally unusual,¹ by virtue of the fact that simplistic Hund's rule based arguments² as well as parity-based models³ would suggest a high-spin triplet ground state for a planar PMP, while the disjointness criterion¹ would suggest that an unusually low-lying excited state or possible ground state singlet might occur. We became interested in this system after one of us⁴ made semiempirical INDO/S-CI computational predictions that various structurally related PMP derivatives would favor a triplet ground state by a small (< 5 kcal/mol) margin. In efforts to obtain evidence for the production of PMP-related species, we synthesized derivatives of 2,4-dibenzylidene-bicyclo(3 1 0)hexan-3-one 2, which through cleavage of its bridgehead C₁-C₅ bond could lead to a PMP derivative that is conformationally constrained relative to 1. In this letter we report the thermal epimerization behavior of a methyl-labeled derivative of 2 and show permissive evidence for formation of a PMP-like intermediate or transition state during this process.



The synthesis of 2 is shown in Scheme I Starting material 4-cyclopentenol 3 is readily available,⁵ and may sequentially be cyclopropanated by the Simmons-Smith procedure to give $4,^6$ oxidized with pyridinium dichromate to 5,⁷ and converted to 2 by a standard aldol procedure using benzaldehyde ⁸ Heating of 2 at about 200°C and photolysis in solution at room temperature showed essentially no change in the ¹HNMR. Photolysis at 77 K in the neat solid and in various frozen solution matrices showed no electron spin resonance spectrum other than adventitious radicals produced from some of the solvents Accordingly, the 6-methyl-labeled derivative **6** was synthesized by modification of the cyclopropanation step in Scheme I to give alcohol 7,⁶ which was oxidized to yield ketone¹⁰ 8 that could be converted to 6^9 (which was found to be completely exo)



Various photolyses of 6 in frozen 2-methyltetrahydrofuran at 77 K gave no observable epimerization, to our disappointment However, the identical photolysis at room temperature in solution rapidly led to a 1 1 epimeric ratio of 6, along with a small amount of unidentified byproducts having olefinic protons in the ¹HNMR. The exo endo ratio in 6 was readily monitored by observing the integrated ratio of the methyl doublets at $\delta 2$ 25 (exo) and $\delta 2$ 56 (endo) ppm ¹⁰ Pyrolysis of 6 in degassed nitrobenzene- d_5 at 150-200°C also readily led to epimerization, this time to give a final endo exo ratio of 0 35-0 41, corresponding to ~1 2 kcal/mol free energy difference between the isomers The epimerization proceeds without formation of byproducts, so far as we can tell by ¹HNMR.

We were unable at this point to differentiate formally between the possibilities of bridge-bond vs "wrongbond" cleavage (9 vs 10 in Scheme I), since to do so would require an enantiomeric labeling/separation synthesis, with attendant complications which we have yet to overcome However, we were readily able to obtain kinetics for the epimerization process in nitrobenzene- d_5 by ¹HNMR, the data for which are shown in Table 1 ¹¹ Analysis of these data yield Eyring parameters of $\Delta H^{\ddagger} = 29$ 8 kcal/mol and $\Delta S^{\ddagger} = -10$ 8 cal/mol-K, corresponding to Arrhenius parameters of $E_a = 310$ kcal/mol and $\log_{10}A = 112$ This is a fairly rapid process for a hydrocarbon epimerization, by comparison to simple cyclopropane isomerization with $E_a = 65$ 1 kcal/mol ¹² It also seems far too facile for a wrong-bond cleavage, by comparison to the study of 2-vinyl-methylcyclopropane epimerization by Ellis and Frey,¹³, in which $E_a = 48$ 6 kcal/mol and $\log_{10}A = 14$ 7 However, our kinetic parameters are very similar to those found by Arai and Crawford for isomerization of *trans*-divinylcyclopropane,¹⁴ which has $E_a = 34$ 3 kcal/mol and $\log_{10}A = 13$ 1

TABLE 1 Thermal Epimerization Rate Constants kep for Compound 6			
<u>Temperature(°C)</u>	<u>10⁵ k_{epi}/sec</u>	<u>Temperature(°C)</u>	<u>10⁵ k_{epi}/sec</u>
164 3	5 40	195 1	57 2
174 5	117	204 5	113 0
185 1	23 0		
(Equilibrated final ratios of exo endo epimers of 6 needed for kinetics were found by heating for > 10 h at each temperature for which kinetics was obtained)			



Table 2 summarizes these kinetic comparisons By analogy, wrong bond cleavage of 6 may be compared to the second entry in Table 2, while bridge-bond cleavage may be compared to the third entry As additional evidence, we find that compounds 11 - 12 do not undergo thermal epimerization under conditions where epimerization of exo-6 proceeds readily, further demonstrating the need to involve both exocyclic benzylidene groups in the epimerization of the bicyclic system, in a manner inconsistent with wrong-bond cleavage



We feel that our data constitutes permissive evidence for formation of a planarizing PMP-type intermediate or transition state 9 in epimerization of 6 While we cannot formally prove planarization without synthesis of other, optically active derivatives of 2, it is hard to see how our observed kinetic parameters may be interpreted in terms of wrong-bond cleavage, given the clear analogy of that process to Ellis and Frey's study We feel that the similarity of our kinetic parameters to those of divinylcyclopropane is entirely in accord with the Borden-Davidson picture of the PMP pi-system as being composed of two allyl fragments weakly coupled by a cross-conjugating group, given that the carbonyl group in 6 has almost no net effect on the activation energy of bond cleavage relative to divinylcyclopropane Further work is underway to investigate possible PMP formation¹⁵ in other variations of this isomerization process, such as in all-hydrocarbon analogs

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- 8 Compound 2 mp 166-167°C, ¹HNMR(300 MHz, CDCl₃) δ 7 18-7 94 (m, 12H, Ar-H), 2 73 (dd, J=4 2 Hz, J=7 9 Hz, 2H, bridgehead CH), 1 84 (pseudo quartet, J=4 2 Hz, J=4 5 Hz, 1H, exo C-H), 1 00 (m, J=7 9 Hz, J"4 5 Hz, 1H, endo C-H), IR(KBr, cm⁻¹) 3028, 3019, 2960 (C-H str), 1697 (s, C=O str), 1617 (vs), 1259, 1188 (vs), 1047, 699, Anal Calcd for C₁₈H₁₄O C 88 20%, H 5 92%, O 5 87% Found C 87 99%, H 5 77%
- 9 Compound 6¹⁰ mp 172-173°C, ¹HNMR(300 MHz, CDCl₃) -- δ 7 21-7 942(m, 12H, Ar-H), 2 44 (d, J=3 4 Hz, 2H, bridgehead CH), 1 52 (d, J = 6 1Hz, 3H, CH₃), 1 25 (m, J=3 4 Hz, J'=6 1Hz, 1H, endo C-H), IR(KBr, cm⁻¹) -- 3025, 2951 (C-H str), 1701 (s, C=O str), 1632 (vs), 1618 (v s), 1260, 1185 (vs), 1045, Anal Calcd for C₁₉H₁₆O -- C 88 08%, H 6 34%, O 5 59% Found C 87 92%, H 6 67%
- 10 The exo isomer assignment for 6 (and corresponding endo assignment in the epimerization) is based on ¹HNMR coupling constants described in J C Rees, D Whittaker, Org Mag Res., 15, 363(1981)
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