Tetrahedron Letters No. 1, pp 57 - 60, 1972. Pergamon Press. Printed in Great Britain.

RING INVERSION IN 2,4-CYCLOOCTADIENONE SYSTEMS

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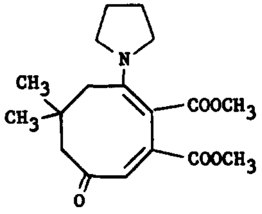
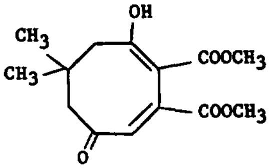
(Received in USA 27 September 1971; received in UK for publication 2 December 1971)

The nmr spectrum of 1, the ring-expansion product of the reaction of the monoenamine derivative of dimedone with dimethyl acetylenedicarboxylate, is characterized by two signals for the geminal methyl protons and two AB patterns for the adjacent ring methylene protons. Acid-catalyzed hydrolysis of 1 produces 2 which exhibits similar nmr patterns for these same protons. The nonequivalence of the ring methvlene protons had been noted previously in the description of the properties of 2 (1), but temperature dependence of the nonequivalence was not studied and nonequivalence of the geminal methyl groups was not reported.



1



2

Nonequivalence in 1 and 2 reasonably is attributed to high barriers to ring conformational inversion similar to that observed in other unsaturated eight-membered ring systems (2). We have evaluated the barriers to ring inversion in 1 and 2 by means of a study of the temperature dependence of the nmr signals for the nonequivalent geminal methyl groups which appear at δ1.01 and δ1.09 in 1 and δ1.00 and δ1.13 in 2 ($CDCl_3$ solution). Shown in Figure 1 are nmr scans of the geminal methyl signals of 1 and 2 over a temperature range including the coalesence point. Data based on these measurements are given in Table 1. Activation free energies for ring inversions were estimated by use of the Erying equation (3) using the rate constants of exchange at coalesence temperatures(4).

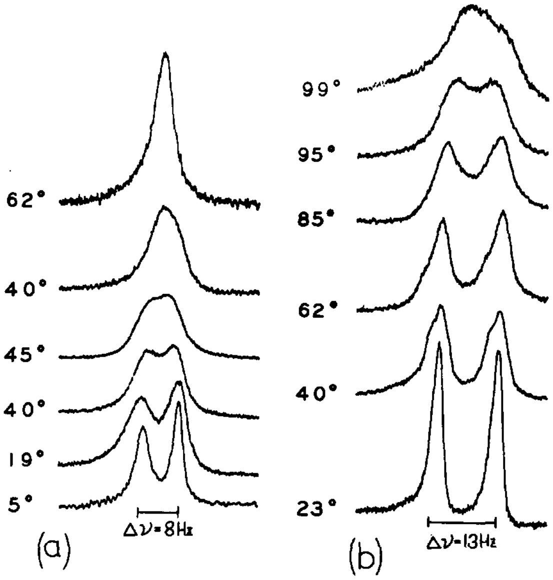


Figure 1.- 100 MHz nmr spectra of geminal methyl singlets of (a) 1 and (b) 2 in $C_2H_2Cl_4$ solution at various temperatures.

TABLE 1

ACTIVATION FREE ENERGIES AND RELATED DATA FOR RING INVERSIONS IN 2,4-CYCLOOCTADIENONES

Compound	T_c(C^o)	$\Delta\nu$ (Hz)	$\Delta G^\ddagger$ (Kcal/mole)	$\Delta\Delta G^\ddagger$
1	45	8	16.8	
2	99	13	19.5	2.7

The ring inversion barriers for 1 and 2 are the first reported for eight-membered rings with five conjugated trigonal atoms. Related structures for which ring inversion barriers are reported include 2,4,6-cyclooctatrienone (E_a = 11.9 kcal/mole) (2a) (seven trigonal atoms); cis-1,2-dibromo-3,5,7-cyclooctatriene ($\Delta G^\ddagger$ = 13 kcal/mole (2b) (six trigonal atoms); and cis-7,8-dideuteriocyclooctatriene ($\Delta G^\ddagger$ = 6.2 kcal/mole) (2c) (six trigonal atoms). The nmr spectrum of cis, cis-1,3-cyclooctadiene (four trigonal atoms) is reported to show temperature dependence characteristic of slow ring inversion at -85° to -110° (2d). Although the approximate methods of calculation (5) make quantitative comparisons inexact, the ring inversion barriers for 1 and 2 appear to be significantly greater than those reported for other unsaturated eight-membered ring systems. The question of whether these relatively large ring inversion barriers result from effects of substituents in 1 and 2, or reflect inherent properties of the parent 2,4-cyclooctadiene system may be considered in light of the observed difference between the barriers for 1 and 2. Inspection of models indicates that ground state conformations of 1 and 2 would include nonplanar arrangements of the ring α, β, γ, δ-unsaturated carbonyl systems. Ring inversion requires a transition state in which this system is brought into a more nearly planar arrangement. Several possible effects of the ring substituents in 1 and 2 on relative energies of the ground and transition states for ring inversion may be considered.

Electronic interaction of the substituents at trigonal ring atoms in 1 and 2 (-COOR and $-NR_2$ or -OH) with the ring α, β, γ, δ-unsaturated carbonyl systems would be expected to stabilize planar, or nearly planar, transition states relative to nonplanar ground states. Furthermore, greater stabilization by delocalization of heteroatom lone pair electrons would be expected for the $-NR_2$ than the -OH substituent. The lower $\Delta G^{\ddagger}$ observed for 1 *vs* 2 is consistent with this expectation.

Steric considerations include the possibilities of destabilization of ground states due to transannular interactions of the *endo*-methyl group, and destabilization of transition states relative to ground states attributed to maximum eclipsing of vicinyl substituents as planarity of the ring is approached. Since the $-NR_2$ substituent is bulkier than the -OH, but the $\Delta G^{\ddagger}$ for 1 is smaller than that for 2, steric factors related to substituents in 1 and 2 must be considered either to destabilize ground states relative to transition states, or, if the opposite is true, to be less important than the electronic effects previously mentioned.

The above conclusions would be weakened by attributing the greater $\Delta G^{\ddagger}$ of 2 relative to 1 to disruption in the transition state of hydrogen bonding of the -OH proton to the carbonyl oxygen of the adjacent -COOR group. However, this possibility is not supported by inspection of models. In summary, therefore, the present evidence indicates that the relatively large ring inversion barriers in 1 and 2 are not due to substituent effects, and that comparably large barriers might be expected for the parent 2,4-cyclooctadienone molecule.

Acknowledgements This work was supported in part by U. S. Public Health Service grant 1 R01 ES00464-01 from the National Institute of Environmental Health Sciences to A. W. H., and by Grant 634 of the University Research Committee of the University of Alabama to R. H. G.

E. J. C. acknowledges the support of a N. D. E. A. Fellowship, 1967-1970. Prof. B. W. Ponder provided helpful comments.

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