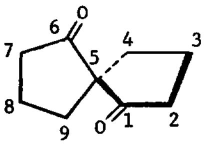
Tetrahedron Letters No. 20, pp 2045 - 2048, 1972. Pergamon Press. Printed in Great Britain.

SOLVENT AND TEMPERATURE DEPENDENT CIRCULAR DICHROISM OF (+)-(5*R*)-SPIRO[4·4]-NONAN-1,6-DIONE

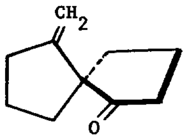
David A. Lightner, Gary D. Christiansen and John L. Melquist
Department of Chemistry, University of California,
Los Angeles, California 90024, U.S.A.

(Received in USA 13 March 1972; received in UK for publication 11 April 1972)

In our investigations of the optical activity of dissymmetric β,γ-unsaturated ketones,[1] we prepared (+)-(5*R*)-spiro[4·4]nonan-1,6-dione (1)[2,3] and (+)-(5*R*)-6-methylidenespiro[4·4]nonan-1-one (2). The optical activity and circular dichroism (CD) spectra of 1 and 2 were of interest to us as their chromophores potentially fall into the inherently dissymmetric classification.[4] Furthermore, 1 is a unique example of a *structurally simple*, optically active β-diketone whose orbital geometries are well-defined[5] and for which there are experimental optical activity data (described herein). Dione 1 was resolved by the method of Gerlach,[6] and enone 2 was prepared by a selective Wittig reaction (47% yield) carried out at room temperature for 30 minutes between 1 and four equivalents of methyltriphenylphosphonium methylide in ether.

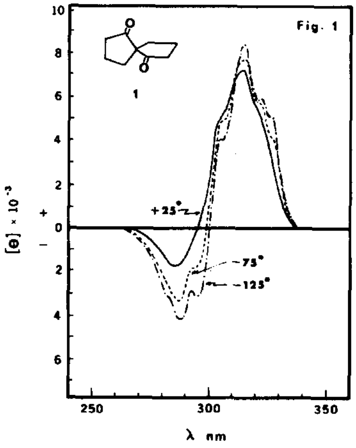


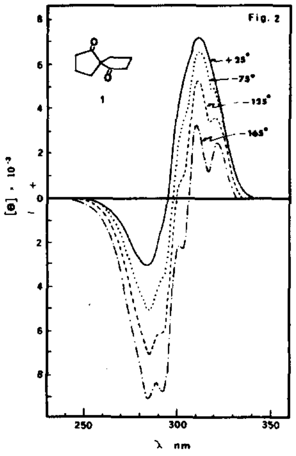
1



2

Earlier investigators showed that dione 1 exhibited significant enhancement of the molecular extinction coefficient (ε) and a bathochromic shift of the long wavelength absorption (log ϵ_{305} 2.1) when compared with the ultraviolet spectrum of cyclopentanone (log ϵ_{290} 1.2) or the monoketone (log ϵ_{295} 1.4) corresponding to 1.[3] Later, Gerlach indicated that the circular dichroism spectrum of 1 exhibited several extrema but did not publish the spectrum.[6] Even more recently, Altona *et al.* determined the configuration of 1 by x-ray methods.[5] The five-membered rings are found to adopt a conformation intermediate between half-chair and envelope (but closer to the former), and this observation is in accord with that predicted by valence-force calculations.[5] These authors also reported that the CD curve of **1** exhibited "a surprising number of peaks."





The temperature and solvent dependent CD spectra of **1** are shown in Figures 1 and 2, whose striking features are the oppositely signed curves in the vicinity of the erstwhile carbonyl n-π* transition. Whereas only minor changes follow temperature variation in isopentane-methylcyclohexane (5:1) solvent (Figure 1), in the more polar and hydroxylic EPA (ether-isopentane-ethanol, 5:5:2) solvent (Figure 2) the changes are much more pronounced. On the other hand, only one maximum is observed in the vicinity of 300 nm in the CD spectrum (λ 308 nm, $\underline{R}^{25} = +2.93$) of enone **2** in isopentane-methylcyclohexane (5:1) or more polar solvents, and only vibrational sharpening in the CD spectra attend temperature changes between +25° and -165°C. These observations may be explained in the following.

According to the approach of Longuet-Higgins and Murrell,[7] when two chromophores are brought sufficiently close together in a molecule, electrostatic coupling of locally excited states with or without charge transfer leads to an absorption spectrum which is not merely the sum of the spectra of the separate chromophores. Application of this theory to (+)-(1R)-5-

methylenebicyclo[2·2·1]hept-2-ene, (+)-(1*R*)-bicyclo[2·2·2]oct-5-ene-2-one and bicyclo[2·2·1]-heptan-2,7-dione using well-known semi-empirical techniques accurately predicts the ordinary absorption spectra and optical activities of the former two compounds; calculations on the latter await experimental verification.[8,9] Applying the method of Hansen[8] to dione **1**, we correctly predict the sign of the long wavelength transition, and the coupling of the two locally excited carbonyl n-π* transitions is manifest in the resultant transitions at λ = 296 and 290 nm as shown in the Table. However, in the region of 300 nm of the calculated CD spectrum the weaker curve is buried under the more intense one to yield a single (positive) maximum. A survey of the results from the superposition of oppositely signed Gaussian curves[10] (of the same band half width) allows us to conclude that in order to observe two distinct, oppositely signed maxima, single curves differing in amplitude by a factor of ten must be separated by at least 15 nm. We believe therefore that although two oppositely signed CD maxima in the vicinity of 300 nm are predicted for **1**, their relative magnitudes are too different (*ca.* a factor of 10 different) and their relative proximity too close to allow for an *observed* separation such as in Figs. 1 and 2.

Table

Calculated[a] and Experimental Optical Properties of (+)-(5*R*)-Spiro[4·4]nonan-1,6-dione

Calculated			Observed	
λ (nm)	Oscillator Strength	Reduced Rotational Strength (cgs)	λ (nm)	Reduced Rotational Strength (cgs)
295	1.19×10^{-4}	+10.6	314	+4.13[b]
290	2.00×10^{-6}	-1.13	287	-0.51[b]
164	0.26	-200	-	-
163	0.22	+202	-	-

[a] Calculations of the coupled chromophore type as described by Hansen (ref. 8).

[b] Measured in isopentane-methylcyclohexane (5:1) at +25°C.

In the case of dione **1**, our observation of two oppositely signed extrema whose relative areas are solvent and temperature dependent coincides with the CD behavior found in the asymmetric solvation of rigid ketones, *viz.* the short wavelength extremum grows at the expense of the long wavelength extremum in going to increasingly polar solvents[11] and lower temperatures.[12] Alternatively, conformational changes might produce the observed CD spectra.[10] In the event this is correct, neither the x-ray determined conformation nor the valence-force calculated conformation[5] of **1** tell the complete story. We prefer to believe that the weight of evidence (x-ray,[5] valence-force calculations,[5] and calculated optical properties, see Table) favors an interpretation of the CD curves based on asymmetric solvation. It is also of interest to note that the positive sign of the Cotton effect associated with the long wavelength transition of enone **2** agrees with prediction based on the chirality rule for β,γ-unsaturated ketones.[4,13]

Acknowledgement: We thank the National Science Foundation (GP9355) and the donors of the Petroleum Research Fund, administered by the American Chemical Society, for support of this research (PRF 4949-ACS). The circular dichroism spectra in this work were obtained with the assistance of Mr. Edward L. Docks. We acknowledge receipt of a sample of camphanic acid from Dr. H. Gerlach. The Cary 60 ORD-CD instrument used in this work was purchased with funds made available by the National Science Foundation (GP1682). Funds for the molecular orbital calculations in this work were made available by the Campus Computing Network of UCLA.

References

1. D. A. Lightner and W. A. Beavers, J. Amer. Chem. Soc., **93**, 2677 (1971).
2. E. H. Hardegger, E. Maeder, H. M. Semarne and D. J. Cram, J. Amer. Chem. Soc., **81**, 2729 (1959).
3. D. J. Cram and H. Steinberg, J. Amer. Chem. Soc., **76**, 2753 (1954).
4. For leading references see C. W. Deutsche, D. A. Lightner, R. W. Woody and A. Moscowitz, Ann. Rev. Phys. Chem., **20**, 407 (1969).
5. C. Altona, R.A.G. DeGraaff, C. H. Leeuwestein and C. Romers, Chem. Comm., 1305 (1971).
6. H. Gerlach, Helv. Chim. Acta, **51**, 1587 (1968).
7. H. C. Longuet-Higgins and J. N. Murrell, Proc. Phys. Soc., **A68**, 601 (1955).
8. A. E. Hansen, Licentiate Thesis. Copenhagen; H. C. Oersted Institute.
9. A. Moscowitz, Proc. Roy. Soc., **A297**, 40 (1967).
10. K. M. Wellman, P.H.A. Laur, W. S. Briggs, A. Moscowitz and C. Djerassi, J. Amer. Chem. Soc., **87**, 66 (1965).
11. A. Rassat, Optical Rotatory Dispersion and Circular Dichroism in Organic Chemistry, G. Snatzke, ed., Sadtler Research Laboratories Inc., Philadelphia, 1965, Chapter 16.
12. A. Moscowitz, K. M. Wellman and C. Djerassi, Proc. Natl. Acad. Sci. (USA), **50**, 799 (1963).
13. A. Moscowitz, K. Mislow, M.A.W. Glass and C. Djerassi, J. Amer. Chem. Soc., **84**, 1945 (1962).