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# CYCLOBUTANE CLEAVAGE OF A SUBSTITUTED TETRACYCLO[4.2.0.0$^{2,8}$,0$^{5,7}$]OCTANE

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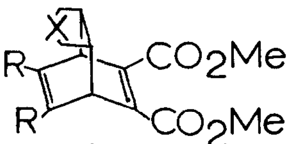
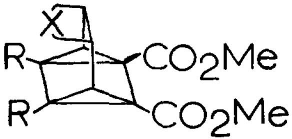
Although very prominant in bicyclo[2.2.1]heptadiene photochemistry[1], the difficulty of observing Cristol closure (internal 2 + 2 cycloaddition) with bicyclo[2.2.2]octodienes has been surprising to many workers.[1] Recently, however, Prinzbach, Eberbach, and Phillipposian[2] have isolated the Cristol closure product from the 2,3-bis(carbomethoxy) derivative and its anti-7,8-methylene derivative, and Liu[3] isolated the closed forms of 2,3-bis(trifluoromethyl) derivatives. We here report our work on an example of this photochemical ring closure reaction to point out the remarkable instability of the closed form.

Reaction of dimethyl acetylenedicarboxylate with 4,5-dimethyl-1,2-dihydrophthalic anhydride[4] (1:1 ratio) at room temperature for three days in $CCl_4$ gave a 30% yield of the Diels-Alder adduct <u>1a</u>, mp 119-120° (crystallized from $CHCl_3$-pentane) in addition to higher adducts. nmr (-30°, $CDCl_3$) δ4.36 (dd, J = 1.5, 2.1Hz, 2 bridgehead H), 3.91 (S,6 methoxy H), 3.50 (dd, J = 1.5, 2.1, 2H), 1.83 (S, 6 methyl H). The addition to 1,2-dihydrophthalic anhydride was very slow at room temperature; at 45° for two days, the yield of <u>1b</u> was quite low, most of the material being converted to higher adducts. nmr: ($CDCl_3$, 45°) δ6.62 (dd, J = 4.4, 3.2, 2 vinyl H), 4.63 (broad mult, 2 bridgehead H), 3.81 (S, 6 methoxy H), 3.48 (dd, J = 1.5, 1.9, 2H).



<u>1</u>

a. R=$CH_3$ X = -COOCO-
b. R=H



<u>2</u>

Irradiation of 1a with a Bausch and Lomb "high intensity" monochrometer set at 313 nm (Osram SP. 200 lamp, slits open) resulted in partial conversion to an extremely labile material with a considerably altered nmr spectrum: (-30°, $CDCl_3$) $\delta$3.80 (S, 6 methoxy H), 3.75 ("t", partially overlaps with methoxyl, 2H), 2.11 ("t", J about 1.9, 2 bridgehead H), 1.45 (S, 6 methyl H). We assign this compound as 2a on the basis of its nmr spectrum and the fact that it opens exclusively to 1a. The following rates for opening of 2a to 1a were observed by successive integration of the upfield methyl singlets ($CDCl_3$ solvent): temperature -10.0°, $k = 1.05 \times 10^{-4} sec^{-1}$; 8.0, $9.90 \times 10^{-4}$; 15.5, $2.30 \times 10^{-3}$; 21.0, $4.06 \times 10^{-3}$. Since deuterochloroform contains traces of acid, and trace amounts of the acid related to 1a could have been present due to adventitious hydrolysis, it was important to establish that acid catalyzed opening was not being observed. 2a prepared by irradiation of 1a in deuterochloroform containing 16 mole % 2,6-lutidine per mole of 1a gave a cleavage rate of $1.10 \times 10^{-3}$ at 8.0°, close to the same as without added base. These rates correspond to $\Delta H^{\neq} \cong 17.6$, kcal/mole $\Delta S^{\neq} \cong -9.6$ eu (least squares values).

Liu's bis(trifluoromethyl) Cristol closure products only decomposed slowly at 80°.[3] This is quite stable compared to Prinzbach's bis(carbomethoxy) examples, which had half-lifes of 12 min. at 19°, and 90 min. at 21.5°.[2] 1a is even less stable, the half-life at 20° being about 3 minutes. It seems likely that the unusual nature of the trifluoromethyl group, which is highly electron withdrawing, yet incapable of conjugation, is responsible for this result. Since the Ea for the quadricyclane ⟶ norbornadiene cleavage is 33.5 kcal/mole[5], it seems reasonable that the stabilizing effect on the transition state for ring opening of carbomethyoxy and methyl substituents, coupled with the extra strain present in the tetracyclo$[4.2.0.0^{2,8}.0^{5,7}]$octane system compared with the tetracyclo$[3.2.0.0^{2,7}.0^{4,6}]$heptane system could lower the activation energy some 16 kcal/mole, as we observe. The entropy term, however, is quite surprising. Quadricyclane has a "normal" single bond cleavage log A of 12.81 ($\Delta S^{\neq}$ about 0).[5] The activation entropy for 2a, however, is comparable to that for reactions with such ordered transition states as Cope rearrangements[6], although virtually the only rotations which can become restricted in the transition state for *2a* opening are those of the carbomethoxy groups. It is interesting to note that the $\Delta S^{\neq}$ observed for *2a* (ca. 9 eu.) is very close to that for Cope rearrangement of *cis*-divinylcyclobutane[7], -11.7 eu. It is, of course, forbidden by symmetry rules for the cyclobutane bonds of *2a* to cleave concertedly, and therefore also for the rotations of both carbomethoxy groups of *2a* to be restricted in the transition state. Further work is clearly necessary for understanding the causes for the unusual opening rate of these very strained systems.

### References

1. H. Prinzbach, *Pure and Applied Chem.*, **16**, 17(1968).
2. H. Prinzbach, W. Eberbach, and G. Philippassian, *Ang. Chem. Int. Ed. Engl.*, **7**, 887(1968).
3. R. S. H. Liu, *Tet. Letters* (18), 1409(1969).
4. Prepared from 4,5-dimethylphthalic acid (W. Ried and K. H. Boenninghausen, *Ann.* *639*, 61(1961)) by 3% sodium amalgum reduction followed by brief heating in acetic anhydride.
5. A. M. Frey, *J. Chem. Soc.*, 365(1964).
6. For a review of unimolecular thermal reactions, see H.M. Frey and R. Walsh, *Chem. Rev.*, **69**, 103(1969).
7. G. S. Hammond and C. D. DeBoer, *J. Am. Chem. Soc.*, **86**, 899(1964).

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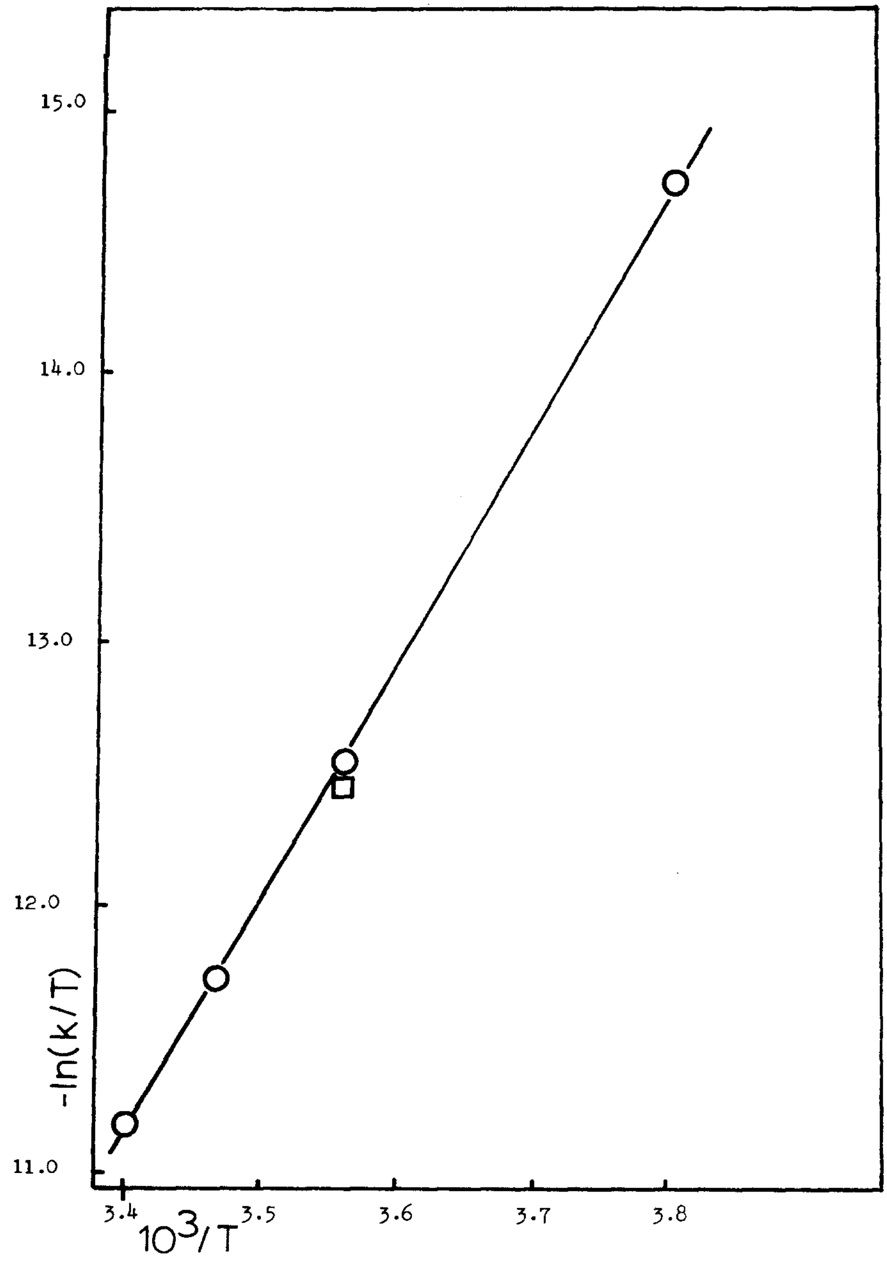

Fig. 1. Rate plot for conversion of 2a to 1a. (Square has 16% 2,6-lutidine added.)