Tetrahedron Letters,Vol.22,No.52,pp 5303-5306,1981 0040-4039/81/525303-04$02.00/0
Printed in Great Britain

THERMAL REARRANGEMENT OF CAGE LACTONES AND RELATED COMPOUNDS
——— DYOTROPIC REARRANGEMENT OF CAGE COMPOUNDS 1)

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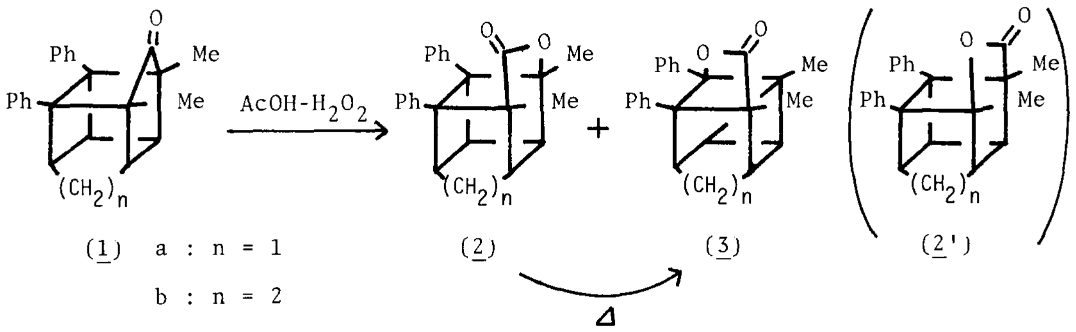
Summary: Thermolyses of cage lactones (2) and their corresponding lactols (7) cause a formal dyotropic rearrangement. These novel reactions in cage system are discussed.

It is well known that strained cage compounds undergo various reactions, such as facile ring opening reactions3) and acid4) or metal ion3a),5) catalyzed rearrangement, involved by its high strain energy. Although a dyotropic rearrangement6) is generally categorized as a high-energy process because of the simultaneous cleavage of two σ-bonds, such a rearrangement would be expected to take place in strained compounds for its high reactivity. In connection with our previous report on the thermal decarbonylations of cage ketones (1),7) we studied thermolyses of cage lactones (2) and their related compounds, where a formal dyotropic rearrangement occurred instead of the expected decarboxylation reactions.

Cage lactones (2) were synthesized by the Baeyer-Villiger oxidation of cage ketones (1). Ketones (1) were unreactive with m-chloroperbenzoic acid or Ce^{4+} ion,8) but oxidation with peracetic acid gave two kinds of lactones; (2a) mp 186-187 °C, (51% yield), and (3a) mp 152-153 °C, (21%); (2b) mp 206-209 °C, (36%), and (3b) mp 146-147.5 °C, (26%), respectively.9),10) The structures of these lactones were proved on the basis of the spectral11) and chemical evidence that δ-lactones (2) easily rearranged to γ-lactones (3) when treated with boron trifluoride.5),8),12) The occurrence of such rearrangement should be ascribed to the relative stability of (3). The expected δ-lactones (2') were not detected in the reaction mixtures. The observed reactivity of the Baeyer-Villiger reactions of (1) is different from that of the corresponding unsubstituted ketone (4).[13]



(1) a : n = 1
b : n = 2
(2)
(3)
(2')

When a benzene solution of δ-lactones (2) was passed through a preheated quarz column at 350 °C, (2) isomerized to (3) quantitatively. These novel thermal reactions are considered to be a formal [2,2] dyotropic rearrangement of cage compounds. The first-order rate constants and the activation parameters for the thermal rearrangement are shown in Table I.[14]

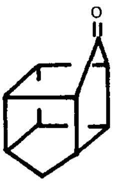
Table I Kinetic data for the thermal reactions of (2)

compd.	Temp. (°C)	$10^5 \times k$ (sec^{-1})	E_a (kcal/mol)*	$\Delta S^\ddagger$ (eu)*
(2a)	230	8.54	36.5±2.8	-5.6±5.6
(2b)	230	13.2	29.5±1.9	-20.4±3.8

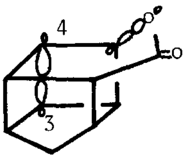
* temperature range 210-240 °C, in o-dichlorobenzene

Although the stepwise process can not be ruled out completely, the negative values of the activation entropies for the rearrangements suggest that the reactions proceed via a concerted mechanism or that there should be appreciable solvation in the transition state.[6a] Thermal ($\sigma_s^2+\sigma_s^2$) reactions are usually symmetrically forbidden process, but these reactions surely become thermally allowed process by participation of the lone pair of the oxygen atom. It should be noted that rearrangement depends on the length of the carbon bridge. Inspection of the molecular models of the lactones (2) reveals that the cyclobutane ring slopes more in (6) than in (5), causing thus the C_3-C_4 bond more parallel to the C-O bond in (6). This might be a reason for readiness of the reaction of (2b) as compared with that of (2a).

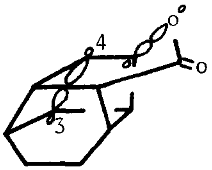
This kind of molecular deformation must be a driving force for dyotropic rearrangements in cage compounds (2).



(4)

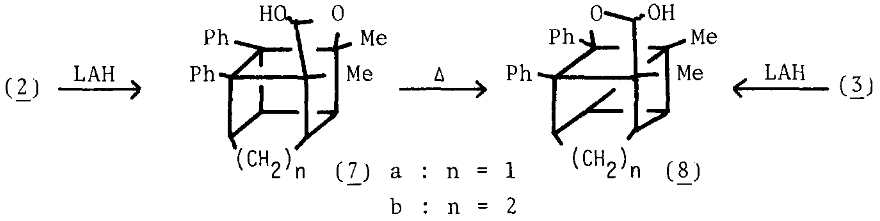


(5)



(6)

To gain more informations, the thermolysis was extended to the related compounds. When the lactols (7), obtained by the reduction of (2) with $LiAlH_4$, were pyrolyzed at 350 °C by the same method as that used for (2), the rearranged products (8) were obtained in 30-40% yields. The structures of (8) were established by direct comparison with the compounds synthesized by the reduction of (3) with $LiAlH_4$.



Thus, the strained cage system seems to be a good model to search for a new rearrangement, because of the capability to vary molecular deformation by changing the length of the carbon bridge. Further studies including substituent effects are in progress to elucidate the reaction mechanism in detail.

References and Notes

1. Organic Thermal Reaction, part 51. Part 50: T. Miyashi, Y. Fujii, Y. Nishizawa, and T. Mukai, J. Am. Chem. Soc., 103, 725 (1981).
2. Present address; Department of Applied Chemistry, Faculty of Engineering, Tokushima University, Minami-Josanjima, Tokushima 770, Japan.
3. a) W. G. Dauben, M. G. Buzzolini, C. H. Schallhorn, and D. L. Whalen, Tetrahedron Lett., 787 (1970).
   b) H. H. Westberg, E. N. Cain, and S. Masamune, J. Am. Chem. Soc., 91, 7512 (1969).
   c) G. Jones, II and B. R. Ramachandran, J. Org. Chem., 41, 798 (1976).

4. a) J. C. Barborak and R. Pettit, J. Am. Chem. Soc., 89, 3080 (1967).
   b) P. R. Schleyer, J. J. Harper, G. L. Dunn, V. J. DiPasquo, and J. R. E. Hoover, ibid., 89, 698 (1967).
   c) W. L. Dilling and C. E. Reineke, Tetrahedron Lett., 2547 (1967).
   d) W. L. Dilling, C. E. Reineke, and R. A. Plepys, J. Org. Chem., 34, 2605 (1969).
   e) W. L. Dilling, R. A. Plepys, R. D. Kroening, J. Am. Chem. Soc., 91, 3404 (1969).
   f) W. G. Dauben and L. N. Reitman, J. Org. Chem., 40, 835 (1975).
5. W. G. Dauben, C. H. Schallhorn, and D. L. Whalen, J. Am. Chem. Soc., 93, 1446 (1971).
6. a) M. T. Reetz, Adv. Organomet. Chem., 16, 33 (1977), and references sited therein.
   b) Z. Goldschmidt and S. Antebi, Tetrahedron Lett., 271 (1978).
7. T. Tezuka, Y. Yamashita, T. Mukai, J. Am. Chem. Soc., 98, 6051 (1976).
8. a) G. Mehta and P. N. Pandey, J. Org. Chem., 41, 953 (1976).
   b) K. Hirao, H. Miura, H. Hoshino, and O. Yonemitsu, Tetrahedron Lett., 3895 (1976).
   c) H. Miura, K. Hirao, and O. Yonemitsu, Tetrahedron, 34, 1805 (1978).
9. Satisfactory elemental analyses were obtained for all new compounds.
10. The relationship between the structures and reactivities in the Baeyer-Villiger reactions of (1) will be reported in detail elsewhere.
11. (2a): ν_{max}(KBr) 1730 cm^{-1}; ^1H NMR(100 MHz,$CDCl_3$) δ_{ppm} 0.84(s,3H),1.37 (s,3H),1.69(m,1H),2.20(m,1H),2.69-2.99(m,2H),3.61-3.82(m,2H),6.9-7.1 (m,10H); (3a): ν_{max}(KBr) 1770 cm^{-1}; ^1H NMR(100 MHz,$CDCl_3$) δ_{ppm} 0.72 (s,3H),0.81(s,3H),1.66(dd,1H),2.31(dd,1H),2.33(m,1H),2.48(m,1H),2.61 (m,1H),3.39(m,1H),6.8-7.4(m,9H),7.69(m,1H); (2b): ν_{max}(KBr) 1740 cm^{-1}; ^1H NMR(100 MHz,$CDCl_3$) δ_{ppm} 0.96(s,3H),1.39(s,3H),1.6-2.1(m,4H),2.17 (m,1H),2.62(dd,1H),2.82(dd,1H),3.38(m,1H),6.9-7.1(m,10H); (3b): ν_{max} (KBr) 1770 cm^{-1}; ^1H NMR(100 MHz,$CDCl_3$) δ_{ppm} 0.76(s,3H),0.89(s,3H), 1.27(dd,1H),1.69(dd,1H),1.7-2.1(m,4H),2.24(m,1H),3.25(m,1H),6.8-7.3 (m,9H),7.64(m,1H).
12. a) R. N. McDonald and G. E. Davis, J. Org. Chem., 34, 1916 (1969).
    b) G. Büchi and I. M. Goldman, J. Am. Chem. Soc., 79, 4741 (1957).
13. The followings are mainly different points compared with the oxidation of (4); 1) ketones (1) are not oxidized by m-chloroperbenzoic acid or Ce^{4+} ion, 2) δ-lactones (2') are not formed, 3) the product ratio of rearranged lactones (3) is greater in the oxidation of (1). See ref. 8.
14. The first-order rate constants and the activation parameters of these reactions were determined by monitoring disappearance of the δ-lactones (2) using nmr spectroscopic method.

(Received in Japan 9 September 1981)