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NOVEL TRANSFORMATION OF CYCLIC 2,4-DIENOLS TO 1,5-EPOXY-3-EN-2-OLS. VANADIUM-CATALYZED EPOXIDATION AND REARRANGEMENT

T. Itoh, K. Jitsukawa, K. Kaneda, and S. Teranishi*

Department of Chemical Engineering, Faculty of Engineering Science,

Osaka University, Toyonaka, Osaka, Japan

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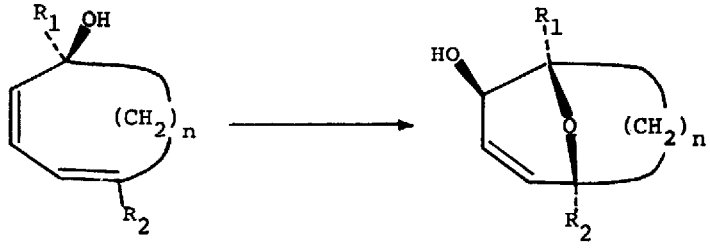
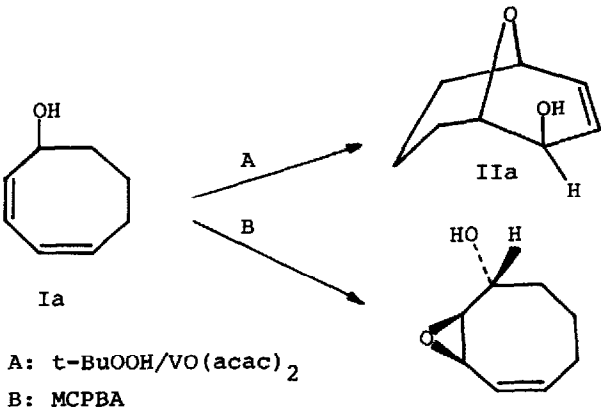
Because of its synthetic utility, increasing interest has been drawn to the highly regio- and stereoselective epoxidation of olefinic alcohols by vanadium catalyst.[1,2] Hitherto, such epoxidation has been believed to occur regioselectively at allylic double bond, without exception.[1a,1b] In this communication, we report a novel transannular epoxidation of cyclic 2,4-dienols to the bridged oxabicyclic compounds having an exo-hydroxy dihydropyran ring.



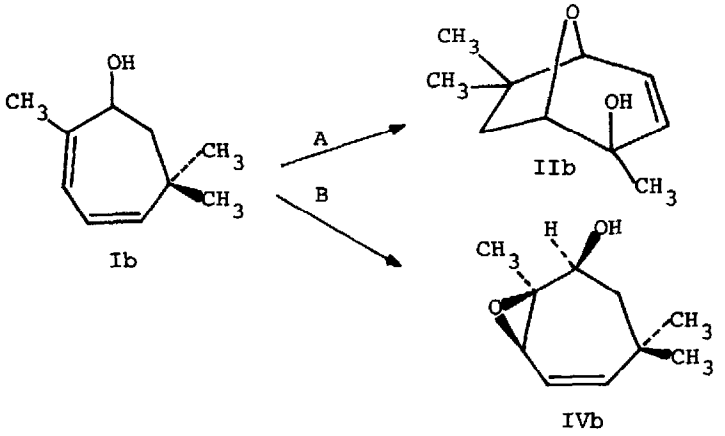
When (Z,Z)-cycloocta-2,4-dienol (Ia) (10 mmol) and t-BuOOH (10 mmol) were treated with vanadyl acetylacetonate [$VO(acac)_2$] (0.10 mmol) in dry benzene (20 ml) at 40° for 50 hr,[3] the major oxygenated product was 9-oxabicyclo[3,3,1]-non-3-en-exo-2-ol (IIa) in 78% yield with 96% isomer-selectivity.[5] Distillation and sublimation gave pure IIa (isolated yield 70% based on Ia), mp 71-72°,[6] IR (dilute CCl_4) 3590, 1070, 1030, 992 cm^{-1}. The structure IIa was confirmed by the NMR spectroscopy (double resonance method) and also by the catalytic hydrogenation over 5% Pd-C in methanol to give 9-oxabicyclo[3,3,1]nonan-exo-2-ol.[7] In contrast, epoxidation of Ia with m-chloroperbenzoic acid (MCPBA) (1.0 equiv) in dichloromethane at 0° for 24 hr gave an oxirane, anti-2,3-epoxy-



cyclooct-4-enol (IIIa), in 91% yield with 99% selectivity. IIIa: bp 93-94°/1.5 mmHg, IR (dilute CCl_4) 3615, 1040, 822 cm^{-1}.

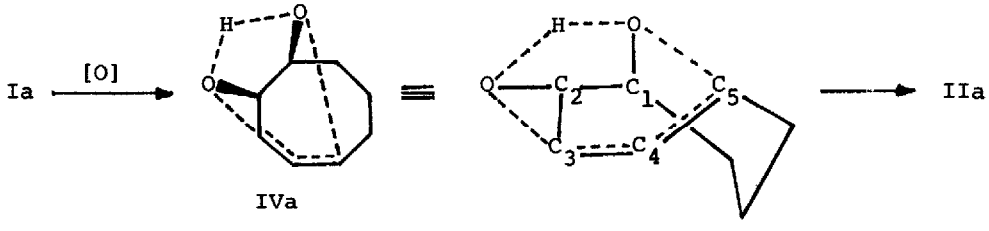
Similar transannular epoxidation occurred to a seven membered ring 2,4-dienol (Ib). Treatment of Ib with t-BuOOH/VO(acac)$_2$ gave a tertiary alcohol, 2,6,6-trimethyl-8-oxabicyclo[3,2,1]oct-3-en-exo-2-ol (IIb) in 86% yield with 99% selectivity. IIb: bp 54-55°/0.7 mmHg, IR(dilute CCl_4) 3583, 1130, 1104, 1036, 1020 cm^{-1}. Epoxidation of Ib with MCPBA followed by short path distillation under reduced pressure (bath temp. $\leq$ 80°) gave a syn-2,3-epoxy-4-enol (IVb) in 65% isolated yield,[8] the result being consistent with the modest syn-stereoselectivity in peracid epoxidation of cyclohept-2-enol.[2] IVb: bp 55-56°/0.5 mmHg, IR (dilute CCl_4) 3595, 1015, 913, 860 cm^{-1}.

The syn-2,3-epoxy-4-enol IVb was thermally rearranged to the exo-hydroxy dihydropyran IIb with perfect stereospecificity under bromobenzene reflux



($t_{1/2} \simeq 3.2$ hr).[9] In the presence of $VO(acac)_2$ catalyst (0.01 equiv), the same rearrangement proceeded more smoothly under milder conditions, e.g., $t_{1/2} \simeq 1$ hr at 60° in benzene solution. On the other hand, neither thermally under bromobenzene reflux for 15 hr, nor catalytically by $VO(acac)_2$, the anti-2,3-epoxy-4-enol IIIa was rearranged to IIa or to its endo-epimer.

All above results indicate that the vanadium catalyzed transannular epoxidation of cyclic 2,4-dienols proceeds by a stepwise mechanism, which involves the stereo- and regioselective epoxidation to syn-2,3-epoxy-4-enols and the subsequent stereospecific rearrangement of them. The latter step is a new type of intramolecular rearrangement of oxirane compounds, which can be characterized by the cooperative participation of three adjacent functional groups, i.e., hydroxyl, oxirane, and carbon-carbon double bond. Probably the intramolecular hydrogen bonding between oxirane oxygen and hydroxyl might play an important role in the double bond migration and the oxirane ring opening. An examination of models suggests that this intramolecular hydrogen bonding constitutes a suitable stereoelectronic arrangement for the six membered ring transition state. Such a situation can not be achieved in the anti-epimers.



Thus, the overall transformation provides a convenient synthetic route to some functionalized oxabicyclic compounds.[10]

References and footnotes

1) (a) M. N. Sheng and J. G. Zajacek, J. Org. Chem., 35, 1839 (1970); (b) K. B. Sharpless and R. C. Michaelson, J. Amer. Chem. Soc., 95, 6136 (1973); (c) S. Tanaka, H. Yamamoto, H. Nozaki, K. B. Sharpless, R. C. Michaelson, and J. D. Cutting, J. Amer. Chem. Soc., 96, 5254 (1974); (d) M. R. Demuth, P. E. Garrett, and J. D. White., J. Amer. Chem. Soc., 98, 634 (1976).

2) Recently we reported that vanadium-catalyzed epoxidation of medium ring allylic alcohols produces syn-2,3-epoxy alcohols selectively, in contrast to peracid reaction giving anti-epimers. T. Itoh, K. Kaneda, and S. Teranishi, J. Chem. Soc., Chem. Commun., (1976) 421.

3) Because of the relatively low reactivity of Ia with t-BuOOH/vanadium reagent and in order to prevent the facile rearrangement of Ia via thermal 1,5-hydrogen shift at elevated temperature (ref. 4), long reaction period and modest reaction temperature were required.

4) S. Moon and C. R. Ganz, J. Org. Chem., 35, 1241 (1970).

5) The minor component of monoepoxidation products was IIIa (4% selectivity). No trace of endo-epimer of IIa was detected by Glc analysis. An authentic sample of the latter epimer was prepared by the Jones oxidation of IIa followed by $NaBH_4$ reduction.

6) All melting and boiling points described here were uncorrected. Satisfactory elemental analyses were obtained for all new compounds.

7) M. Barrelle and M. Apparu, Bull. Soc. Chim. Fr., (1972) 2016.

8) From the distillation residue was obtained in 14% yield a mixture of two diepoxy alcohols, which were tentatively assigned to 2,6,6-trimethyl-anti, anti-2,3;4,5-diepoxy-cycloheptanol and its 4,5-syn-epimer.

9) Under our Glc conditions, e.g., OV-17, column temp. 120°, injection temp. 150°, IVb was converted to IIb. Therefore, the rearrangement was followed by NMR spectroscopy. As the reaction proceeds, the C_2-methyl proton signal of IVb at 8.56 τ is displaced with that of IIb at 8.92 τ.

10) This cyclization to oxabicyclic compounds is unique and clearly differentiated from the well known organometallic reagent-induced cyclizations (ref. 11).

11) L. A. Paquette, I. R. Dunkin, J. P. Freeman, and P. C. Storm, J. Amer. Chem. Soc., 94, 8124 (1972) and references cited therein. See also ref. 7.