The C_7H_9 Cation Manifold. Interconversion of a Series of Potentially Bishomoantiaromatic Ions

Sir:

The concepts of antiaromaticity,[1] homoantiaromaticity,[2] and bishomoantiaromaticity[3] of cationic species have received considerable attention in the last few years. Recently, we suggested[4] the intermediacy of **1**, a potentially bishomoantiaromatic cation, in the solvolytic rearrangement of *endo-anti*-tricyclo[3.1.1.$0^{2,4}$]heptan-6-ol (**2**). We now wish to present evidence which shows that **1** is a member of a series of interconverting cations of the formula C_7H_9. In addition, we have found that there is a distinct lack of support for the presence of any bishomoantiaromatic character among the members of this manifold of equilibrating C_7H_9 cations.

Whereas **2** gave no products containing either the tricyclo[3.1.1.$0^{2,4}$]heptyl skeleton or the tricyclo[4.1.0.$0^{2,4}$]heptyl nucleus on solvolysis in buffered acetic acid, solvolysis in 60:40 v/v diglyme–water containing sodium borohydride gave **3**, **4**, **5**, and the product of proton loss, cycloheptatriene (**6**) in 11, 13, 35, and 13% yields, respectively.[5,6] Although the isolation of **3** provided convincing evidence for the presence of a species which can be reduced to give this tricyclic hydrocarbon, it did not establish whether this species was the cation **1**, which was convertible to **7** and **8**, or whether there was a single highly delocalized bishomoantiaromatic ion, such as **9**, involved. In principle, borohydride reduction of **9** could give **3**, **4**, and **5**. In order to clarify this point, we have entered this cation system from different directions.

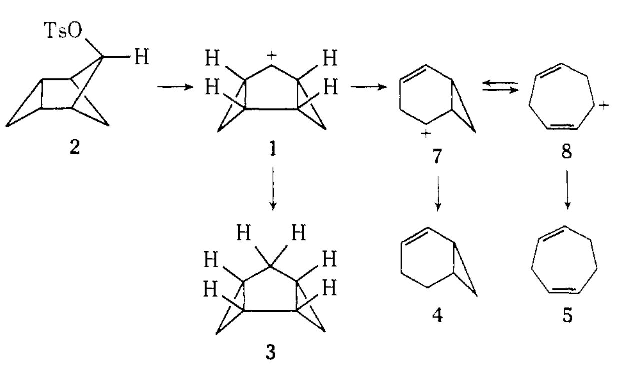

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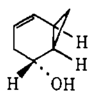
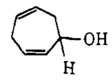
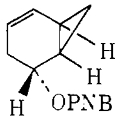
Table I. Ratio of Products Obtained in the Solvolysis of C_7H_9 Cation Precursors

				Product ratios		
						
Compd	Temp, °C	Method[a]	Yield, %	**14**	**15**	**6**
2	25	A	98	11	36	53
10	120	B	75	6	31	63
11	120	B	79	8	30	62
12	120	B	78	3	33	64
13	80	A	*b*	4	37	58

[a] Method A involves solvolysis of the tosylate **2** or triflate **13** in acetic acid buffered with sodium acetate, followed by lithium aluminum hydride reduction of the crude product mixture. Method B involves solvolysis in 70:30 v/v acetone–water buffered with triethylamine. [b] Absolute yields not determined in this case.

Compounds **10**, **11**, **12**, and **13** all represent carbocation precursors which should provide a portal to the ion(s) in question. Table I lists the product ratios obtained from **2**, **10**, **11**, **12**, and **13**. Although considerable differences exist in temperatures, solvent, and leaving groups, the same three products are found in all of the solvolyses. The differences in product ratio, although small, appear to be outside the limits of error of determination by vpc analysis. The largest percentage change occurred in the amount of **14**. Whereas **2** gave 11% of **14**, **10** and **11** gave *ca.* 5–6%, and **12** gave *ca.* 2%. This indicates that there may be some dependence of the product ratio on the nature of the cation precursor.



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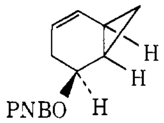

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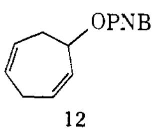

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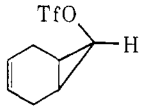

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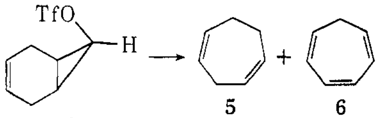
Since borohydride is more nucleophilic than either water or acetic acid, it should be able to intercept the ion manifold at an earlier stage if interconverting ions are involved (rather than a species such as **9**). Treatment of **13** in 60:40 v/v diglyme–water at 55° with sodium borohydride gave 55% of **5** and 25% of **6**.



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No trace of **3** or **4** could be detected. This indicates that the borohydride is capturing an ion in the solvolysis of **13** at a different stage of equilibration than that observed in borohydride trapping experiments with **2**. *This completely rules out the intermediacy of a single bishomoantiaromatic ion such as* **9**.

The data presented above provide ample evidence that the solvolysis of **2** leads initially to **1**, which is subsequently converted to **7**. The isolation of **3** and **4** is only consistent with the capture of **1** and **7** by borohydride. The formation of **14** in the solvolysis of **10**, **11**, **12**, and **13** in the presence of oxygen nucleophiles,

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(1) M. Saunders, R. Berger, A. Jaffe, J. M. McBride, J. O'Neill, R. Breslow, J. M. Hoffman, Jr., C. Perchonock, E. Wasserman, R. S. Hutton, and V. J. Kuck, *J. Amer. Chem. Soc.*, **95**, 3017 (1973); R. Breslow and J. M. Hoffman, Jr., *ibid.*, **94**, 2110 (1972); R. Breslow, *Chem. Eng. News*, **43**, 90 (June 28, 1965).

(2) P. Vogel, M. Saunders, N. M. Hasty, Jr., and J. A. Berson, *J. Amer. Chem. Soc.*, **93**, 1551 (1971).

(3) A. F. Diaz, M. Sakai, and S. Winstein, *ibid.*, **92**, 7477 (1970); A. F. Diaz, D. L. Harris, M. Sakai, and S. Winstein *Tetrahedron Lett.*, 303 (1971); J. J. Gajewski and C. N. Shih, *ibid.*, 2967 (1970).

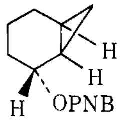
(4) P. G. Gassman and X. Creary, *J. Amer. Chem. Soc.*, **95**, 2729 (1973).

(5) It is interesting to note that no trace of tricyclo[3.1.1.$0^{2,4}$]heptane could be found in this trapping experiment. This supports our earlier contention[4] that the solvolysis of the tosylate **2** involved neighboring group participation to lead directly to the cation **1**.

(6) Compounds **4**, **5**, and **6** were identified *via* comparison with authentic samples. The structure of **3** was established through comparison of its spectral properties with those previously reported in the literature for tricyclo[4.1.0.$0^{2,4}$]heptane [W. Kirmse and K. Pöhlmann, *Chem. Ber.*, **100**, 3564 (1967)].

such as water and acetic acid, and the absence of **4** in the solvolysis of **13** in the presence of borohydride require that **7** and **8** be interconverting in the less nucleophilic media.

Additional evidence against the intermediacy of a bishomoantiaromatic ion, such as **9**, was provided by a kinetic study of the solvolysis of **10**, **11**, **12**, and their reduced counterparts, **16**, **17**, and **18**. As can be seen from Table II, the effect of the added double bond on the rate of solvolysis varies from 17 for the ratio of **16** to **10** to 1.9 for the ratio of **18** to **12**. These rate decelerations are of a magnitude which might be expected due to the electron-withdrawing effect of the added double bond. Their size is far less than might be expected for a significant destabilization of the incipient carbocation as a result of bishomoantiaromaticity. Thus, no evidence for the presence of any significant effect due to bishomoantiaromaticity could be detected.



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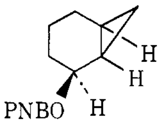

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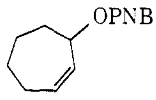

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Table II. Solvolysis of Saturated–Unsaturated Pairs in 70:30 v/v Acetone–Water

Compd	Temp, °C (±0.03°)	Rate, sec^{-1}	$\frac{k_{\text{sat}}}{k_{\text{unsat}}}$
10	100.0	(3.50 ± 0.03) × 10^{-5}	
16	100.0	(6.08 ± 0.01) × 10^{-4}	17
11	100.0	(3.89 ± 0.01) × 10^{-5}	
17	100.0	(5.08 ± 0.04) × 10^{-4}	13
12	120.0	(5.49 ± 0.03) × 10^{-5}	
18	120.0	(1.02 ± 0.01) × 10^{-4}	1.9

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(7) Goodyear Fellow, 1972–1973.

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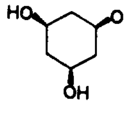
A Novel Synthesis of Prostaglandin $F_{2\alpha}$

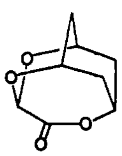
Sir:

We wish to communicate a stereospecific route to a new and versatile precursor of the prostaglandin class and its conversion to the title compound. The method described features the use of functional groups in intermediates as internal protecting agents, in a manner which at the same time serves the further purpose of providing excellent stereochemical control in the synthetic operations.

cis-Cyclohexane-1,3,5-triol (I)[1] was converted to the crystalline tricyclic lactone II[2] (mp 142–143°, yield 85%) by refluxing its solution in 1,2-dimethoxyethane for 30 min with an equal weight of glyoxylic acid monohydrate and an excess of Amberlyst 15.[3]

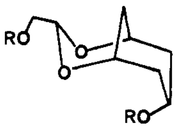


I



II

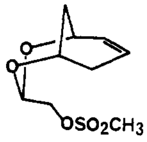
Sodium borohydride reduction in absolute ethanol for 2 hr at 20° transformed II into the bicyclic diol IIIa (mp 149–151°, yield 97%) which in turn, when treated with 2 equiv of methanesulfonyl chloride in pyridine at −20°, yielded the dimesylate IIIb (mp 139–140°, yield 97%).



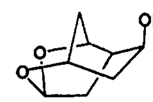
III

a: R=H
b: R=CH_3SO_2

When a hot suspension of the latter in either ethanol or isopropyl alcohol was mixed with a boiling solution of potassium hydroxide in the same solvent, the olefin mesylate IV (mp 54–59°, yield 89%) was formed after a brief period of reflux. When solvolyzed in boiling water–1,2-dimethoxyethane 5/1 (v/v) for 18 hr in the presence of 1 equiv of potassium carbonate, IV furnished the tricyclic carbinol Va (mp 231–238° (evacuated capillary), yield 70%).



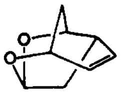
IV



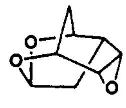
V

a: R=H
b: R=CH_3SO_2

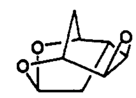
Va could be obtained more directly (overall yield from IIIb, 61%) by dilution of the reaction solution containing IV with aqueous potassium bicarbonate, removal of the bulk of ethanol (or isopropyl alcohol) *in vacuo*, and refluxing the resulting solution for 18 hr in a nitrogen atmosphere. With methanesulfonyl chloride and triethylamine in methylene chloride at 0°, Va afforded the crystalline mesylate Vb (mp 102–104°, yield 95%), which on boiling in isopropyl alcoholic potassium hydroxide solution for 2 hr yielded the crystalline and highly acid-sensitive tricyclic olefin VI (mp 111° (sealed capillary), yield 93%). The reagent prepared *in situ* from hydrogen peroxide, benzonitrile, and potassium bicarbonate in methanol[4] at room temperature preferentially approached the double bond of VI from the concave side of the molecule. As a result the crystalline epoxide VII was formed as the major product (mp 166–168° (sealed capillary), yield 62%). It was separated from the isomeric, less polar epoxide VIII (mp 181–182°



VI



VII



VIII

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(1) H. Stetter and K. H. Steinacker, *Ber.*, **85**, 451 (1952).

(2) Elemental analytical data in excellent agreement with that calculated for the empirical formulas of all crystalline intermediates have been obtained.

(3) Supplied by Rohm and Haas Co., Philadelphia, Pa.

(4) G. B. Payne, *Tetrahedron*, **18**, 763 (1962).