## A Synthesis of Ketones by the Thermal Isomerization of 3-Hydroxy-1,5-hexadienes. The Oxy-Cope Rearrangement<sup>1</sup>

Sir:

Cope rearrangements of 1,5-hexadienes, whether of the double-inversion (C-1-C-6 bond formation)<sup>2,3</sup> or single-inversion (C-1-C-4 bond formation)<sup>4</sup> type, generate a new double bond between C-2 and C-3 of the six-atom system. Attachment of a hydroxyl group to C-3 should give the progenitor of an enol, thus permitting the synthesis of carbonyl compounds by ketonization of the rearrangement product  $(1 \rightarrow$  $2 \rightarrow 3$ ). The present paper reports both double-



inversion and single-inversion examples of this reaction, for which the term "oxy-Cope rearrangement" is proposed.

Bicyclo [2.2.2] oct-5-en-2-one (4)<sup>5</sup> and vinylmagnesium bromide react to give a 2:1 mixture of 2-endovinyl-2-exo-hydroxybicyclo [2.2.2]octene (**5a**)<sup>6</sup> and the 2-exo-vinyl-2-endo-hydroxy epimer 6a.6 The isomers are separated by vapor chromatography (v.p.c.); each absorbs 2 moles of hydrogen to give 2-ethylbicyclo [2.2.2]octanol-2,6 m.p. 39.5-42.5°, identical with



an authentic sample prepared from 2-bicyclo[2.2.2]octanone and ethylmagnesium iodide. The infrared method which formed the basis for the assignments of stereochemistry to the bicyclo [2.2.2] octenols 5b and 6b<sup>7</sup> does not distinguish between 5a and 6a, but the configurations of the latter compounds follow from their chemical behavior and their nuclear magnetic resonance (n.m.r.) spectra. The methine hydrogen of the vinyl group of the major isomer (5a) from the Grignard addition absorbs as a multiplet centered further upfield ( $\tau$  4.30) than the corresponding absorption (at  $\tau$  4.17) of the minor isomer (**6a**),<sup>8</sup> suggesting

(1) This work was supported in part by the Directorate of Chemical Sciences, Air Force Office of Scientific Research Grant No. AF-AFOSR 389-63, and by funds provided by the Wisconsin Alumni Research Foundation.

(2) A. C. Cope and E. M. Hardy, J. Am. Chem. Soc., 62, 441 (1940), and later papers by Cope and co-workers.

(3) For a review, see S. J. Rhoads in "Molecular Rearrangements," P. de Mayo, Ed., John Wiley and Sons, Inc., New York, N. Y., 1963.

(4) (a) G. S. Hammond and C. D. De Boer, J. Am. Chem. Soc., 86, 899 (1964); (b) D. J. Trecker and J. P. Henry, ibid., 86, 902 (1964). (5) Prepared according to K. Mislow and J. G. Berger, ibid., 84, 1956

(1962).

(6) Elemental analysis establishes the empirical composition.
(7) H. L. Goering, R. W. Greiner, and M. F. Sloan, J. Am. Chem. Soc., 88, 1391 (1961).

(8) Similar results are observed? with methyl Grignard reagent, the major isomer (probably 5c) showing the methyl singlet n.m.r. peak further upfield than that of the minor isomer.

(9) J. A. Berson and N. Kundu, unpublished observations.

diamagnetic shielding by the  $\pi$ -electrons of the endocyclic double bond<sup>10</sup> in 5a.

Heating 5a in the gas phase at 320° in an ammoniawashed, evacuated glass tube gives  $cis-\Delta^{5,6}$ -octalone-2  $(7)^6$  as the major product (90%) of the volatile material, 50% isolated yield). The infrared spectrum of 7 ( $\lambda\lambda_{max}$  1720 and 1650 cm.<sup>-1</sup>) suggests a nonconjugated unsaturated ketone. Hydrogenation gives pure  $cis-\beta$ -decalone, uncontaminated by the trans isomer. The n.m.r. spectrum shows two olefinic hydrogens,



which, taken with the previous evidence, restricts the structure of the rearrangement product to  $cis-\Delta^{5,6}$ octalone-2 (7) and the  $\Delta^{6,7}$  (8) and  $\Delta^{7,8}$  (9) isomers.



The latter two structures are highly unlikely on mechanistic grounds and are eliminated from consideration by conversion of the rearrangement product via hydroboration and oxidation to a mixture of two diketones in the ratio of 7:3. The major diketone isomer has a v.p.c. retention time and infrared spectrum identical with those of authentic 1,6-decalindione  $(10)^{11}$ ; its disemicarbazone, m.p. 233-234° dec., does not depress the melting point of authentic material on admixture. Only 7 of the three octalones can give 10 by this sequence. The second diketone isomer is presumably 11.



The  $5a \rightarrow 7$  reaction is formulated as a Cope rearrangement of the double inversion type, leading to the enol of 7, followed by ketonization. Detailed consideration of the mechanism is deferred.<sup>12</sup>

7-Norbornenone<sup>13</sup> (12) reacts with vinylmagnesium bromide to give a 4:1 mixture of syn-7-vinyl-anti-7hydroxynorbornene (13),<sup>6</sup> m.p. 58.2-59.8°, and anti-7vinyl-syn-7-hydroxynorbornene (14).6 Each of the



<sup>(10)</sup> If these assignments are correct, Grignard additions show a stereochemical preference opposite to that of lithium aluminum hydride reductions of 4, since the latter reaction gives<sup>517</sup> more 6b than 5b.

(12) (a) Cf. J. A. Berson and M. Jones, Jr., ibid., 86, 5017 (1964). The formula numbers correspond to those of the accompanying paper.<sup>124</sup> (13) P. G. Gassman and P. G. Pape, J. Org. Chem., 29, 160 (1964).

<sup>(11)</sup> W. S. Johnson, D. S. Allen, Jr., R. R. Hindersinn, G. N. Sausen, and R. Pappo, J. Am. Chem. Soc., 84, 2181 (1962). We thank Professor Johnson for kindly supplying a sample of 10.

alcohols consumes 2 moles of hydrogen to give 7ethyl-7-norbornanol,<sup>6</sup> m.p.  $65.5-66.5^{\circ}$ , independently prepared from 7-norbornanone and ethylmagnesium iodide. Infrared studies show that the major isomer (13) does not have an intramolecular hydrogen bond while the minor isomer (14) does. The preference for syn addition of the vinyl Grignard reagent to 12 is in accord with the observed<sup>14</sup> course of the reaction of methyl Grignard reagent with 12.

Pyrolysis of the syn-vinyl compound 13 at  $250^{\circ}$  gives the double-inversion product *cis*-bicyclo[4.3.0]nonen-2-one-7 (15)<sup>6</sup> corresponding to 7, but this mode of rearrangement now is subordinate (10% of the volatile materials) to the single-inversion path which leads to bicyclo[3.2.2]nonen-6-one-2 (16),<sup>6</sup> m.p. 89-90.8° (84% of the volatile products, 66% isolated yield). An additional 5-6% of minor products is formed.<sup>12b</sup>



The structure of 16 is established by the infrared spectrum ( $\lambda_{max}$  1708 cm.<sup>-1</sup>), by a concordant (but not uniquely decisive) n.m.r. spectrum, and by hydrogenation to 2-bicyclo [3.2.2] nonanone,<sup>6</sup> m.p. 152.5-154.5°, which is also formed<sup>9</sup> by pyrolysis of the barium salt of *cis*-4-carboxycyclohexanepropionic acid. Compound 15 can be hydrogenated to cis-1-hydrindanone, has an infrared maximum at 1740 cm,  $^{-1}$  (nonconjugated cyclopentanone), and shows n.m.r. absorptions as multiplets at  $\tau$  4.35 (area 2), 7.18 (area 1), and 7.7-8.4 (area 9). Of the seven possible 7-cisbicyclo [4.3.0] nonenones, all but 15, 17, and 18 may be eliminated on the grounds of obvious incompatibility with the gross spectral data. The latter two are both mechanistically improbable and furthermore are not in accord with the details of the n.m.r. spectrum, as will be described in the full paper.



The  $13 \rightarrow 16$  isomerization provides one of the simplest entries into the bicyclo [3.2.2]nonane system, and the general sequence of vinylation and thermal rearrangement suggests a new synthetic route for conversion of  $\beta$ ,  $\gamma$ -unsaturated ketones to bis homologous  $\delta$ ,  $\epsilon$ -unsaturated ketones.

(14) R. K. Bly and R. S. Bly, J. Org. Chem., 28, 3165 (1963). DEPARTMENT OF CHEMISTRY JEROME A. BERSON UNIVERSITY OF WISCONSIN MAITLAND JONES, JR. MADISON, WISCONSIN

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## Isomeric Carbonium Ions. Ring Expansion of the syn- and anti-2-Norbornene-7-carbinyl Systems<sup>1</sup> Sir:

The ring expansions<sup>2</sup> of *syn*-2-norbornene-7-carbinyl derivatives (II) involve intermediates distinctly different from those given by *anti* precursors III.

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The products of acetolyses (at reflux in the presence of 10-20% excess sodium acetate) of the *p*-bromo- and *p*-nitrobenzenesulfonates (IIa, IIb, IIIa, IIIb) of the syn and anti series, as well as those obtained from the nitrosative deamination in glacial acetic acid at 25° of the amines (IIc and IIIc),<sup>3</sup> fall into three main



categories: (i) the "Le Bel" series (L), IV, V, VIc, VII, previously observed<sup>4</sup> to result from carbonium

is made to the donors of this fund. We are also indebted for support to the Wisconsin Alumni Research Foundation.

(2) For previous studies of other systems, see J. A. Berson and P. Reynolds-Warnhoff, J. Am. Chem. Soc., 84, 682 (1962); 86, 595 (1964); J. A. Berson and D. Willner, *ibid.*, 84, 675 (1962); 86, 609 (1964).

(3) (a) Previous studies of the acetolysis of IIa at 115° reported products IId (91%), XIIb (8%), and the remainder unidentified; IIIa was reported to give 90% IIId, 4% XIIb, and the remainder unidentified.<sup>3b</sup> Acetolyses of IIa and IIIa (OBs = OTs) were reported to give "essentially unrearranged" products.<sup>3c</sup> (b) R. K. Bly, R. S. Bly, and J. E. Goldberg, Abstracts, 146th National Meeting of the American Chemical Society, Denver, Colo., Jan., 1964, p. 6C; (c) R. R. Sauers and R. M. Hawthorne, Jr., J. Org. Chem., 29, 1685 (1964).

(4) (a) N. A. Le Bel and J. E. Huber, J. Am. Chem. Soc., 85, 3193 (1963).
(b) cf. R. R. Fraser and S. O'Farrell, Tetrahedron Letters, 1143 (1962). (c) Product V, formed in very small yield in our system, was not observed in the previous case but would have escaped detection there if present in comparable amount.<sup>46</sup>