crease in k_4 due to a change in termination mechanism as R goes from a tertiary to a primary group.[13,14]

Thus it is clear that k_t for BO· is on the order of 10^9 M^{-1} sec^{-1}, while that for BOO· is about 10^4 M^{-1} sec^{-1}. The value of k_t obtained from direct irradiation of purified BOOB is a strong indication that the species at $g = 2.004$ is BO·. A g value for this radical would be predicted to be greater than 2.0023 due to the higher spin–orbit coupling constant for oxygen than for carbon.[16] Similarly the g value for BO· should be lower than that of HO· which is reported to be 2.01.[17] Furthermore the lack of hyperfine splitting and the spectral width rule out a radical with the unpaired spin on carbon bearing a hydrogen atom.[18] Certainly the species at $g = 2.004$ is not BOO·. We are hard pressed to envision a radical produced on irradiation of neat BOOB which is not BO·, BOO·, or a carbon radical with a hydrogen atom attached to the carbon bearing the unpaired spin.

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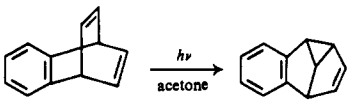
(16) A. Carrington and A. D. McLachlan, "Introduction to Magnetic Resonance," Harper and Row, Publishers, New York, N. Y., 1967.
(17) J. Kroh, B. C. Green, and S. W. I. Spinks, *Can. J. Chem.*, **40**, 413 (1962).
(18) R. W. Fessenden and R. H. Schuler, *J. Chem. Phys.*, **39**, 2147 (1963).

Steven Weiner, George S. Hammond
Contribution No. 3740, Gates and Crellin Laboratories of Chemistry
California Institute of Technology, Pasadena, California 91109
Received November 4, 1968

An Unusual Substituent Effect in the Photorearrangement of Benzobicyclo[2.2.2]octadienols

Sir:

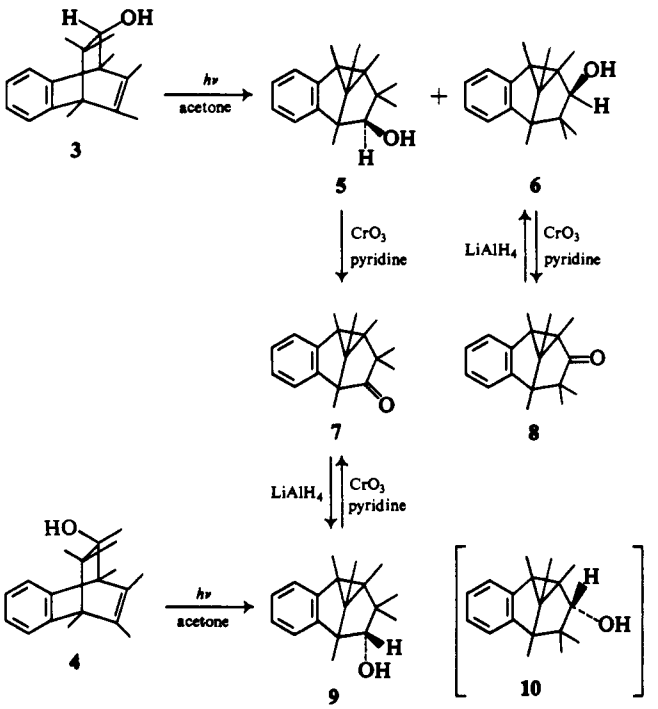
Several recent reports[1] have described the photosensitized rearrangement of benzobarrelenes to benzosemibullvalenes. Zimmerman[1a] has shown that the transformation **1** → **2** is the result of vinyl–vinyl, not benzo–vinyl,



1 **2**

bridging. However, di-π-methane rearrangements[2] which do involve benzo–vinyl bridging have been observed in the dibenzobarrelene to dibenzosemibullvalene[1b,3] and benzonorbornadiene[4] to tetracyclo[5.4.0.0^{2,4}.0^{3,6}]undeca-1(7),-8,10-triene photorearrangements. We have examined the photochemistry of the related epimeric *anti*- and *syn*-1,3,3,4,7,8-hexamethyl-5,6-benzobicyclo[2.2.2]octa-5,7-diene-2-ols (**3** and **4**, respectively) and have found a most unusual substituent effect.

Irradiation of the *anti* alcohol **3**[5] with acetone sensitization through a Corex filter with a Hanovia L 450-W lamp, when allowed to proceed to 85% conversion, provided a 73% yield of a 3:2 mixture of two alcohols, **5** and **6**.[6] Alcohol **5**, mp 81–83°, shows in the infrared[7] a band at 3638 cm^{-1}, and its nmr spectrum consists of three-proton singlets at τ 9.88, 9.03, 8.95, 8.83, 8.67, and 8.63, a one-proton singlet at τ 6.78, and an aromatic multiplet, τ 2.94–3.04 (4 H). Oxidation of **5** with CrO_3–pyridine gave ketone **7**: mp 87–88.5°; $\nu_{C=O}^{CCl_4}$ 1725 cm^{-1}; $\lambda_{max}^{95\%\,EtOH}$



3 **5** **6** **7** **8** **4** **9** **10**

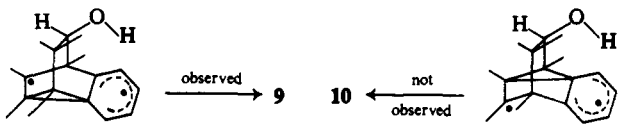
292 mμ (ε 1290) with shoulders at 313 (800), 301 (1230), and 247 mμ (2980); nmr spectrum: three-proton singlets at τ 9.50, 9.00, 8.80, 8.77, 8.58, and 8.50, and an aromatic multiplet, τ 2.92–3.08 (4 H). Alcohol **6**, mp 90–92°, has in the infrared[7] a band at 3642 cm^{-1}, and its nmr spectrum consists of three-proton singlets at τ 9.33, 9.13, 8.90, 8.85, 8.80, and 8.67, a one-proton singlet at τ 7.08, and an aromatic multiplet, τ 2.94–3.20 (4 H). Oxidation of **6** with CrO_3–pyridine yielded ketone **8**: mp 100–102°; $\nu_{C=O}^{CCl_4}$ 1720 cm^{-1}; $\lambda_{max}^{95\%\,EtOH}$ 278 (ε 1150) and 270 mμ (1370) with a shoulder at 263 mμ (1450); nmr spectrum (CD_3CN): three-proton singlets at τ 9.44, 8.90, 8.74, 8.68, 8.63, and 8.57, and an aromatic multiplet, τ 2.90–3.22

(1) (a) H. E. Zimmerman, R. S. Givens, and R. M. Pagni, *J. Am. Chem. Soc.*, **90**, 4191 (1968); (b) P. W. Rabideau, J. B. Hamilton, and L. Friedman, *ibid.*, **90**, 4465 (1968); (c) J. P. N. Brewer and H. Heaney, *Chem. Commun.*, 811 (1967); (d) R. S. H. Liu, *J. Am. Chem. Soc.*, **90**, 215 (1968).
(2) H. E. Zimmerman, R. W. Binkley, R. S. Givens, and M. A. Sherwin, *ibid.*, **89**, 3932 (1967).
(3) E. Ciganek, *ibid.*, **88**, 2882 (1966).
(4) J. R. Edman, *ibid.*, **88**, 3454 (1966).
(5) A. C. G. Gray and H. Hart, *ibid.*, **90**, 2569 (1968).
(6) All new compounds reported here gave satisfactory elemental analyses.
(7) In *syn*-5,6-benzobicyclo[2.2.2]octen-2-ols, a band at 3586 cm^{-1} has been attributed to internal hydrogen bonding with the aromatic ring, whereas the 3620-cm^{-1} band in the *anti* epimer has been assigned to the free hydroxyl: K. Kitahonoki and Y. Takano, *Tetrahedron Letters*, 1597 (1963). Similar values have been reported for the *syn*- and *anti*-5,6-benzobicyclo[2.2.2]octa-5,7-dien-2-ols.[4] The ν_{O-H} therefore clearly establish the configurations of **5**, **6**, and **9**, as shown.

(4 H).[8] Reduction of ketone **8** with lithium aluminum hydride provided only the *anti* alcohol **6**.

In contrast with the anti alcohol **3**, *similar irradiation of the* syn *alcohol* **4**[4] *provided only a single alcohol*, **9**.[9] Alcohol **9**, mp 72–73°, shows in the infrared[7] a band at 3580 cm^{-1}, and its nmr spectrum contains three-proton singlets at τ 10.00, 9.02, 8.93, 8.83, 8.67, and 8.62, a broad one-proton signal, τ 6.53–6.73, and an aromatic multiplet, τ 2.88–3.13 (4 H). Oxidation of **9** with CrO_3–pyridine provided ketone **7**, while reduction of **7** with lithium aluminum hydride yields only the *syn* alcohol **9**.

Thus, whereas the acetone-sensitized irradiation of the *anti* alcohol **3** gave both possible isomers **5** and **6**, identical irradiation of the *syn* alcohol **4** gave a single product, **9**. No **10** was formed. The regiospecificity[10] in the latter rearrangement indicates a strong preference for intermediate **11** *vis-à-vis* **12**. No such preference is observed when the hydroxyl group is in the *anti* position. Possible factors which may contribute to the preference of **11** over **12** may be hydrogen bonding or charge-transfer inter-



11 **12**

action with the oxygen. Further studies to determine the nature of the interaction which controls the course of this photorearrangement are in progress.

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(8) This ketone was identical with the product of acetone-sensitized irradiation of 1,3,3,4,7,8-hexamethyl-5,6-benzobicyclo[2.2.2]octa-5,7-dien-2-one: H. Hart and R. K. Murray, Jr., *Tetrahedron Letters*, in press.

(9) Irradiation to only 18% conversion of **4** gave a 97% yield of **9**; at 80% conversion, the yield of **9** was 68%.

(10) A. Hassner, *J. Org. Chem.*, **33**, 2684 (1968).

(11) National Institutes of Health Predoctoral Fellow at Michigan State University, 1967–1968.

Harold Hart, Roger K. Murray, Jr.[11]
Department of Chemistry, Michigan State University
East Lansing, Michigan 48823
Received November 8, 1968

Studies on Polypeptides. XLII. Synthesis and Characterization of Seven Fragments Spanning the Entire Sequence of Ribonuclease T_1[1-3]

Sir:

For some time this laboratory has been engaged in studies aimed at a total synthesis of the proposed amino acid sequence of the enzyme ribonuclease T_1.[4] Reports[5,6] on the synthesis of materials possessing some ribonuclease A activity prompt us to disclose at this time the status of our investigations.

We have completed the synthesis and careful characterization of seven protected fragments spanning the entire sequence of the enzyme.

Ribonuclease T_1 contains only one residue each of lysine and arginine and no methionine; moreover, three of the four half-cystines are located in the N-terminal region. The presence in the enzyme of 12 glycine residues allows subdivision of the chain into a number of fragments of convenient size which C-terminate in glycine. It was for these reasons that we selected T_1 for synthetic studies.

Our plan of synthesis (Figure 1) involves construction of six fragments (A to F), each terminating with a protected hydrazide, and a C-terminal tetracosapeptide amide (G) followed by assembly of these component parts into the complete sequence by azide coupling steps. This approach is patterned according to a scheme proposed in 1952[7] except that *t*-butoxycarbonyl[8,9] rather than benzyloxycarbonylhydrazides were employed; the benzyloxycarbonylhydrazide of tyrosine was used in the construction of fragment A.

Preparation of fragments B–E involved conversion of the C-terminal benzyloxycarbonyl di- or tripeptides into the corresponding *t*-butoxycarbonylhydrazides, removal of the benzyloxycarbonyl function by hydrogenolysis, followed by stepwise elongation of the chains[10] with the desired benzyloxycarbonylamino acid N-hydroxysuccinimide[11] 2,4,5-trichlorophenyl[12] or *p*-nitrophenyl[13] esters. Benzyloxycarbonyl dipeptide azides were also used in some instances. The aspartic and glutamic acid side chains were protected with *t*-butyl esters.[14] The α-amino group of alanine-1 and the ϵ-amino group of lysine-41 were protected by formyl groups since it appears[15] that deamination of these residues does not destroy the catalytic activity of the enzyme. Similarly, since the C-terminal threonine residue can be removed with carboxypeptidase without loss of enzyme activity,[16] it was replaced by threonine amide. Fragment F was prepared by azide coupling of two protected peptides corresponding to positions 66–74 and 75–80, respectively. Three fragments corresponding to positions 95–104, 89–94, and 81–88 served to construct fragment G.

The presence of three cysteine residues in fragment A necessitated a different approach from that employed

(1) See R. Andreatta and K. Hofmann, *J. Amer. Chem. Soc.*, **90**, 7334 (1968), for paper XLI in this series.

(2) Supported by the U. S. Public Health Service and the Research Laboratories Edgewood Arsenal, Contract DA-18-035-AMC-307 (A). The opinions expressed in this communication are those of the authors and do not reflect endorsement by the contractor.

(3) The amino acids except glycine are of the L configuration. DMSO, dimethyl sulfoxide; DMF, dimethylformamide; TEA, triethylamine; TFA trifluoroacetic acid; O-*t*-Bu, *t*-butyl ester; EC ethylcarbamyl; F, formyl; TCP, 2,4,5-trichlorophenyl; X, *t*-butoxycarbonylhydrazide; Y, benzyloxycarbonylhydrazide; Z, benzyloxycarbonyl; AP-M, aminopeptidase M. See ref 1 for solvent systems used for tlc chromatograms.

(4) K. Takahashi, *J. Biol. Chem.*, **240**, PC4117 (1965).

(5) B. Gutte and R. B. Merrifield, *J. Amer. Chem. Soc.*, **91**, 501 (1969).

(6) R. Hirschmann, R. F. Nutt, D. F. Veber, R. A. Vitali, S. L. Varga, T. A. Jacob, F. W. Holly, and R. G. Denkewalter, *ibid.*, **91**, 507 (1969).

(7) K. Hofmann, A. Lindenmann, M. Z. Magee, and N. H. Khan, *ibid.*, 74, 470 (1952).

(8) R. A. Boissonnas, St. Guttmann, and P.-A. Jaquenoud, *Helv. Chim. Acta*, **43**, 1349 (1960).

(9) R. Schwyzer, E. Surbeck-Wegmann, and H. Dietrich, *Chimia* (Aarau), **14**, 366 (1960).

(10) M. Bodanszky and V. du Vigneaud, *J. Amer. Chem. Soc.*, **81**, 5688 (1959).

(11) G. W. Anderson, J. E. Zimmerman, and F. Callahan, *ibid.*, **86**, 1839 (1964).

(12) J. Pless and R. A. Boissonnas, *Helv. Chim. Acta*, **46**, 1609 (1963).

(13) M. Bodanszky, *Nature*, **175**, 685 (1955).

(14) (a) R. Schwyzer and H. Dietrich, *Helv. Chim. Acta*, **44**, 2003 (1961); (b) R. Schwyzer and H. Kappeler, *ibid.*, **44**, 1991 (1961).

(15) Y. Shiobara, K. Takahashi, and F. Egami, *J. Biochem.* (Tokyo), **52**, 267 (1962).

(16) K. Takahashi, *ibid.*, **52**, 72 (1962).