Tetrahedron Letters, Vol.22, No.36, pp 3501 - 3504, 1981
Printed in Great Britain

0040-4039/81/363501-04$02.00/0

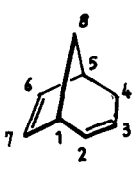
REACTION OF BICYCLO[3.2.1]OCTADIENE WITH 4-METHYL-1,2,4-TRIAZOLINE-3,5-DIONE: COMPETITIVE DIPOLAR AND HOMO-CYCLOADDITION

Waldemar Adam* and Ottorino De Lucchi

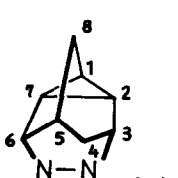
[Institute of Organic Chemistry, University of Würzburg, D-8700 Würzburg, Am Hubland, West-Germany and Department of Chemistry, University of Puerto Rico, Rio Piedras, Puerto Rico 00931, USA]

SUMMARY: The nonconjugated bicyclo[3.2.1]octa-2,6-diene (1) affords with 4-methyl-1,2,4-triazolin-3,5-dione (MTAD) the homo-cycloadduct (2) product and the rearranged urazoles (3) and (4) through dipolar cycloaddition, while ene-reaction and (2+2)-cycloaddition are not observed.

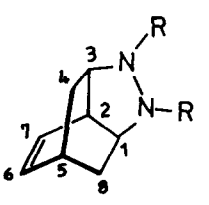
Bicyclo[3.2.1]octa-2,6-diene (1), although a nonconjugated diene and thus incapable of (2+4)-cycloaddition, is nevertheless expected to show a great diversity of dienophilic reactivity. For example, it could react with 4-methyl-1,2,4-triazolin-3,5-dione (MTAD) via (2+2)-cycloaddition[1] at the C_2-C_3 and the C_6-C_7 sites, ene-reaction[1a,2] at the C_4 position, homo-cycloaddition[3] at the C_2-C_7 and C_3-C_6 sites and dipolar cycloaddition[4] at the C_2-C_3 and C_6-C_7 sites. Thus, (1) constitutes an ideal substrate to explore the competitive nature of these diverse cycloaddition routes.



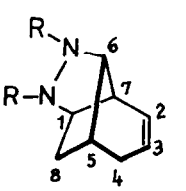
(1)



(2)



(3)



(4)

R+R = $-\overset{O}{\overset{\|}{C}}-N(CH_3)-\overset{O}{\overset{\|}{C}}-$ (numbering of product skeletons refers to that of 1)

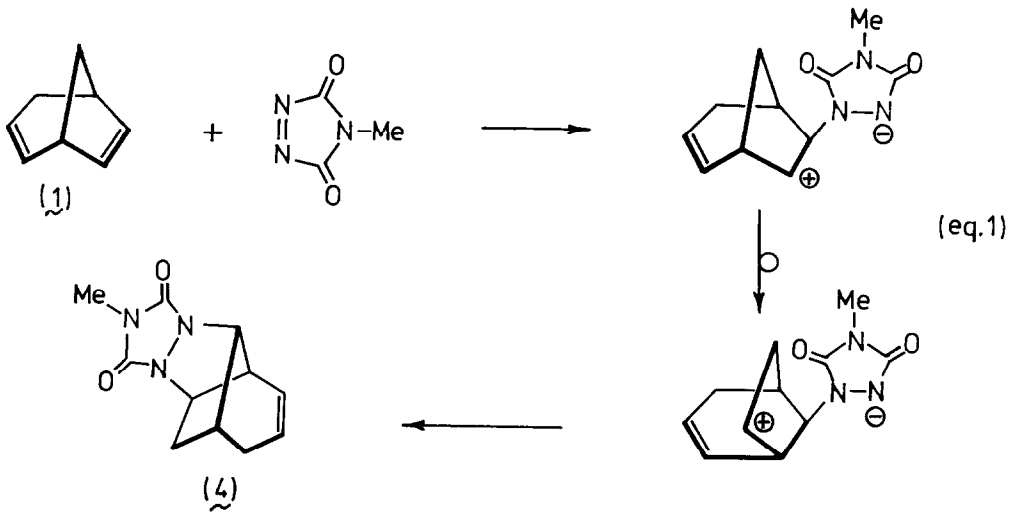
We report that in the reaction of MTAD with (1) dipolar cycloaddition competes effectively with homo-cycloaddition, but both the ene- and (2+2)-routes are not observed. To the best of our knowledge (1) constitutes the first bicyclodiene for which dipolar cycloaddition wins over homo-cycloaddition.[5]

While (1) is unreactive towards maleic anhydride and even singlet oxygen, tetracyanoethylene leads to an intractable product mixture. However, on reaction of a ca. 0.5 M solution of (1) in CH_2Cl_2 with ca. 1.5-fold molar excess of MTAD at 25°C for 48 h, the three urazoles (2) to (4) are formed in 31, 11 and 37% yields[6], respectively (as determined by ^1H NMR). The pure compounds were isolated by silica gel chromatography using CH_2Cl_2 as eluant. Satisfactory elemental analysis and ^1H and ^{13}C NMR and IR spectral data support the proposed structures of the urazoles.[7]

The minor course of reaction of (1) with MTAD is homo-cycloaddition to afford urazole (2). Although the ^{13}C-H coupling constants of ca. 170 Hz suggested that urazole (2) contains a cyclopropane ring, an unequivocal structure assignment of (2) was only possible on X-ray analysis. Not even traces of homo-cycloaddition with cyclobutane formation, i.e. attack at the C_2-C_7 site was observed, showing that cyclopropane formation, i.e. attack at the C_3-C_6 site, is prefered. Inspection of Dreiding models suggests easier access in (1) for the cyclobutane homo-adduct, but no examples of this mode of homo-cycloaddition appear to be reported.[5]

Both dipolar cycloaddition routes[4] are observed for (1), leading to the rearranged urazoles (3) and (4), of which attack on the more strained double bond (C_6-C_7 site) affording (4) predominates. While the determination of the structure of (3) was straightforward in view of its high degree of symmetry, an unequivocal assignment of the double bond position in (4) was difficult on the basis of its spectral data.[7] For this purpose we prepared the corresponding urazole from 4,4-dimethylbicyclo[3.2.1]octa-2,6-diene with MTAD. The gem-dimethyl substitution simplified the ^1H NMR spectrum sufficiently, so that on high field analysis the double bond could be placed with certainty as assigned in urazole (4). Furthermore, on mechanistic grounds urazole (4) would be the expected product[5], as shown in Eq.1.

The lack of ene-reactivity of (1) towards MTAD is at first surprising, but its 6,7-benzo derivative shows similar behavior towards PTAD.[8] Inspection of Dreiding models of (1) implies that the allylic hydrogens at C-4 are not well alligned for ene-reaction.[1a,9] The fact that (2+2)-cycloaddition is not observed in the MTAD reaction of (1) suggests that this forbidden cycloaddition



mode requires higher activation energies and is thus not competitive. Only under more drastic conditions, especially when other cycloaddition routes are prevented, does (2+2)-cycloaddition take place.[1]

In conclusion, the bicyclodiene (1) illustrates that of its various possible cycloaddition modes, i.e. dipolar-, homo-, ene- and (2+2)-routes, only the first two take place, with the dipolar route being prefered. The reasons for this selectivity are not apparent at this point and to provide an understanding, it seems essential to explore in detail the product patterns of other complex bicyclodienes that exhibit competitive cycloaddition behavior.

ACKNOWLEDGEMENTS are made to the Deutsche Forschungsgemeinschaft, the Fonds der Chemischen Industrie, the Donors of the Petroleum Research Fund, administered by the American Chemical Society, the National Institutes of Health and the National Science Foundation for generous financial support. We thank Dr. D. Scheutzow for the high resolution ^{1}H NMR spectra, Professors H. Hopf (Braunschweig) and R. Neidlein (Heidelberg) for the ^{13}C spectra and Dr. K. Peters (MPI Stuttgart) for the X-ray determination.

REFERENCES:

1. a) C. A. Seymour and F. D. Greene, J. Am. Chem. Soc., 102, 6384 (1980).
b) W. Adam and O. De Lucchi, Tetrahedron Letters, 929 (1981).
2. a) H. M. R. Hoffmann, Angew. Chem. Int. Ed. Engl., 8, 556 (1969).

b) A. Gopalan, R. Moerck and P. Magnus, J. Chem. Soc. Chem. Comm., 548 (1979).

c) S. Ohashi and G. B. Butler, J. Org. Chem., 45, 3472 (1980).

3. R. C. Cookson, S. S. H. Gilani, I. D. R. Stevens, J. Chem. Soc.C., 1905 (1967).

4. W. Adam, O. De Lucchi and I. Erden, J. Am. Chem. Soc., 102, 4806 (1980).

5. W. Adam and O. De Lucchi, Angew. Chem. Int. Ed. Engl., 19, 762 (1980).

6. The product distribution is 5:1:4 for PTAD as dienophile.

7. Urazole (2), 14% yield, mp 156.5-157°C (prisms from EtOH); ^{1}H NMR ($CDCl_3$, TMS) δ(ppm): 1.30-2.20 ($H_{1,2,4,7,8}$, 7H, m); 2.45 (1H, q, J=6Hz); 3.10 ($N-CH_3$, 3H, s); 4.60 (CHN, 1H, m); 4.77 (CHN, 1H, dd, J=3.6 and 6Hz). ^{13}C NMR ($CDCl_3$, TMS) δ(ppm): 155.80 (s, CO); 154.12 (s, CO); 57.89 (d); 50.09 (d); 33.78 (t); 33.59 (t); 31.12 (d); 25.18 (q); 19.57 (d); 16.73 (d); 16.50 (d). IR (KBr) ν(cm^{-1}): 3075, 3000, 2980, 2960, 2900, 1770, 1710, 1465, 1400, 1350, 1300, 1270, 1215, 1180, 1125, 1080, 1020, 1000, 940, 930, 870, 830, 790, 760, 740, 720, 610. Urazole (3), 4% yield, mp 143-144°C (needles from ether): ^{1}H NMR ($CDCl_3$, TMS) δ(ppm): 1.70 ($H_{4(8)}$, 4H, m); 2.72 (H_5, 1H, broad s); 3.06 ($N-CH_3$, 3H, s); 3.10 (H_2, 1H, m, $J_{1,2}$=9.3Hz); 4.18 ($H_{1(3)}$, 2H, dd, $J_{1(3),4(8\text{-exo})}$=4.8Hz); 6.00 (H_7, 1H, m, $J_{6,7}$=8.4Hz, $J_{2,7}$=6.6Hz, $J_{5,7}$=1.5Hz); 6.60 (H_6, 1H, m, $J_{5,6}$=6.6 Hz). ^{13}C NMR ($CDCl_3$, TMS) δ(ppm): 156.71 (s, CO); 140.73 (d); 123.74 (d); 54.54 (d); 42.20 (d); 33.65 (d); 27.35 (t); 25.35 (q). IR (KBr) ν(cm^{-1}): 3035, 2970, 2860, 1765, 1700, 1450, 1400, 1360, 1220, 1100, 1070, 1010, 940, 910, 860, 810, 760, 700, 600. Urazole (4), 19% yield, mp 90-91°C (needles from ether): ^{1}H NMR ($CDCl_3$, TMS) δ(ppm): 1.73-2.70 ($H_{4,5,7,8}$, 6H, m); 3.05 ($N-CH_3$, 3H, s); 4.18 (CHN, 1H, broad s); 4.58 (CHN, 1H, m); 5.68 ($H_{2,3}$, 2H, m). ^{13}C NMR ($CDCl_3$, TMS) δ(ppm): 158.63 (s, CO); 158.34 (s, CO); 128.16 (d); 123.35 (d); 66.11 (d); 62.34 (d); 45.48 (d); 35.38 (t); 34.47 (d); 33.04 (t); 25.57 (q). IR (KBr) ν(cm^{-1}): 3040, 2945, 2900, 2840, 1765, 1700, 1450, 1390, 1360, 1260, 1200, 1150, 1085, 1050, 1030, 1020, 990, 770, 750, 690, 620.

8. W. Adam, N. Carballeira and O. De Lucchi, J. Am. Chem. Soc., 102,2107(1980)

9. a) A. A. Frimer, Chem. Revs., 79, 359 (1979). b) K. N. Houk, J. C. Williams Jr., P. A. Mitchell and K. Yamaguchi, J. Am. Chem. Soc., 103, 949 (1981).

(Received in Germany 3 June 1981)