Chem. Ber. **117**, 1977 – 1979 (1984)

Acid-catalyzed Cyclization of the Ene-Product Derived from α-Pinene and PTAD

Waldemar Adam, Ottorino de Lucchi*), William D. Gillaspey,* and *Robert J. Rosenthal**)*

Institut für Organische Chemie der Universität Würzburg,
Am Hubland, D-8700 Würzburg (FRG)

Received October 10, 1983

Säurekatalysierte Cyclisierung des En-Produkts aus α-Pinen und PTAD

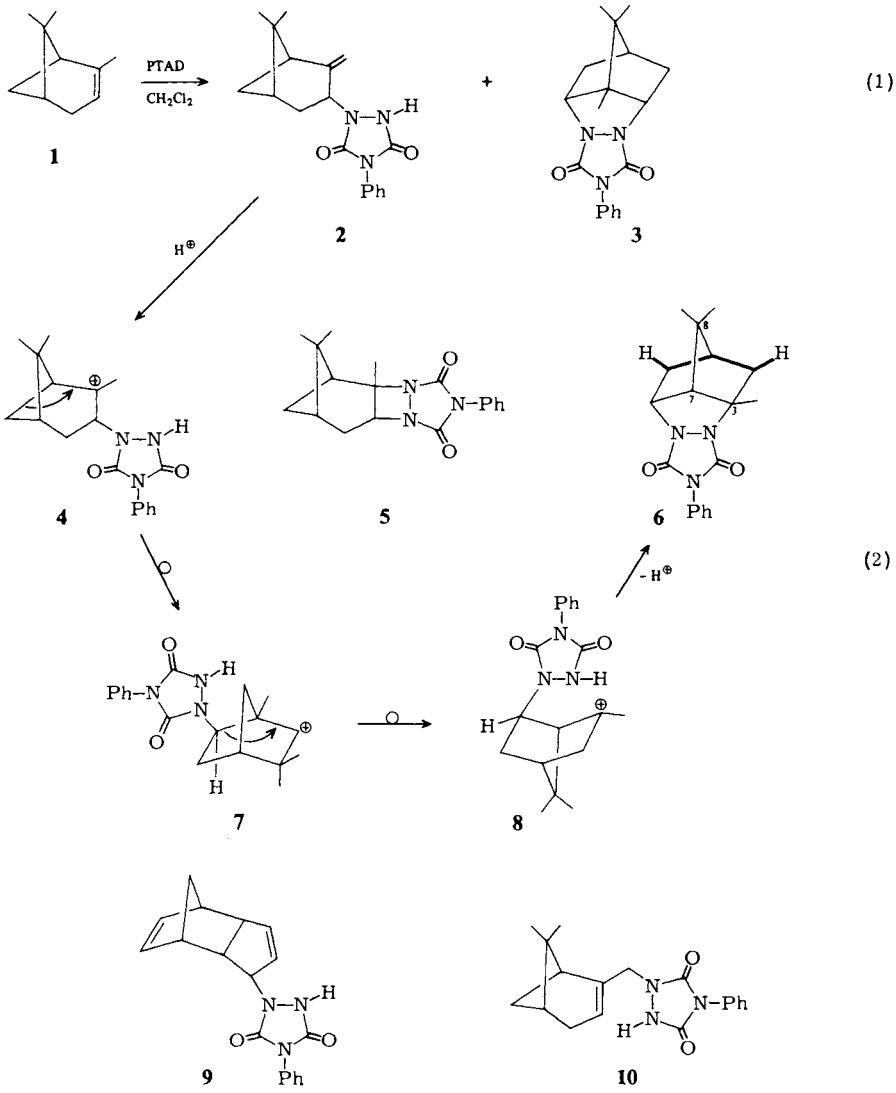
Aluminiumchlorid-katalysierte Reaktion des En-Produkts **2** aus 4-Phenyl-4*H*-1,2,4-triazol-3,5-dion (PTAD) und α-Pinen (**1**), des 1-(6,6-Dimethyl-2-methylenbicyclo[3.1.1]hept-3-yl)-4-phenyl-1,2,4-triazolidin-3,5-dions, ergab 3,8,8-Trimethyl-*N*-phenyl-4,5-diazatricyclo[4.2.1.$0^{3,7}$]nonan-4,5-dicarboxamid (**6**) in 78% Ausbeute. Auch Bortrifluorid-etherat, trockener Chlorwasserstoff und *p*-Toluolsulfonsäure katalysieren die Cyclisierung von **2** zu **6**, aber nicht in diesem Maße. Der Mechanismus der Cyclisierung wird über eine Gerüstumlagerung der Carbenium-Ionen-Zwischenstufen gedeutet.

In the synthesis of azoalkanes via hydrolysis and subsequent oxidation of the urazole resulting from the cycloaddition of triazolediones (TAD) and olefinic substrates, the formation of ene-products is usually a menacing side reaction. For example, we recently reported[1] that α-pinene (**1**) and 4-phenyl-4*H*-1,2,4-triazole-3,5-dione (PTAD) afforded predominantly the ene-product **2** besides the desired rearranged urazole **3**, Eq. (1). In the interest of utilizing such "dead-end" products of PTAD, we investigated the acid-catalyzed reaction of the ene-product **2**. Direct cyclization of the resulting cation **4** could afford the diazetidine **5**, while skeletal rearrangements involving migration of the isopropylidene or the methylene bridges could lead to the rearranged urazoles **3** and **6**, respectively. All of these urazoles would be of interest to us in view of their potential azochemistry[2]. In this note we report that the acid-catalyzed reaction of **2** gives exclusively the rearranged urazole **6** in high yield.

Treatment of the ene-product **2** with *p*-toluenesulfonic acid in benzene, dry hydrogen chloride in methanol, boron trifluoride in ether, and aluminum trichloride in dichloromethane all gave the rearranged urazole **6** as a colorless, crystalline solid, but the yields were highest (ca. 80%) in the case of aluminum trichloride. The elemental analysis confirmed that urazole **6** was isomeric with the ene-product **2** and the IR spectrum revealed the presence of the urazole carbonyl bands at 1765 and 1719 cm^{-1}. The ^{13}C NMR spectrum exhibited, besides the urazole carbonyl and phenyl carbons, ten distinct aliphatic carbons, i. e. three quartets for the methyl carbons, two triplets for the methylene ring carbons, three doublets for the methinyl bridge-head carbons, and two singlets for the quaternary bridgehead and *gem*-dimethyl-substituted carbons, all in the expected chemical shift range (cf. Experimental Part).

*) Present address: Institute of Organic Chemistry, University of Padova, Italy.
**) Alexander von Humboldt Fellow (1982 – 83).

0009 – 2940/84/0505 – 1977 $ 02.50/0



The similarity of the ^{13}C NMR spectrum of the product with that of urazole **3**[1] provided the first clue that the structurally similar urazole **6** rather than the azetidine **5** had been formed. Rigorous structure proof was provided by the 400 MHz ^1H NMR spectrum, employing extensive decoupling experiments. The results and assignments are summarized in the Experimental Part. The key feature in this assignment was the observation of a substantial W-coupling (J = 3.5 Hz) between 9-*exo*-H and 2-*exo*-H as established by decoupling experiments. For example, irradiation of the 9-*exo*-H at δ = 2.44 (dddd) resulted in the collapse of the ddd pattern of the 2-*exo*-H at δ = 2.28 into a dd pattern (J = 14.0 and 3.5 Hz). As in the case of the urazole **3**[1], the pyrazolidine moiety acts as a vice, providing the necessary rigidity for a large W-coupling[3]. Inspection of molecular models confirmed that no W-coupling should be observed in azetidine **5**.

As to the formation of urazole **6**, we propose the mechanism shown in Eq. (2) for the proton-catalyzed rearrangement of ene-product **2**. Thus, addition of a proton at the methylene terminus leads first to the cation **4**, which on migration of the methylene bridge affords cation **7**. The unfavorable stereochemistry of the urazole group requires rearrangement of **7** into the cation **8**, which on cyclization and deprotonation affords urazole **6**. Precedents for such skeletal rearrangements in monoterpene chemistry have been documented[4].

The general scope of this novel acid-catalyzed cyclization of ene-products into rearranged urazoles appears to be limited. For example, treatment of the ene-products **9** and **10** either with protic acids or with Lewis acids gave complete decomposition of the starting materials. However, in favorable cases, as demonstrated here for the ene-product **2**, such acid-catalyzed cyclization might constitute an effective route for rearranged urazoles that cannot be made directly via cycloaddition of TAD to olefinic substrates.

We thank the *Deutsche Forschungsgemeinschaft*, the *Fonds der Chemischen Industrie* and the *Alexander von Humboldt-Stiftung* for generous financial support.

Experimental Part

IR spectra: Beckman Acculab 4. – ^1H and ^{13}C NMR spectra: Bruker WH-400 spectrometer. – Mass spectra: Varian MAT CH-7. – The elemental analyses were determined for us by Prof. Dr. *G. Maier's* staff (University of Gießen). – The ene-product **2** was prepared as previously described[1].

3,8,8-Trimethyl-N-phenyl-4,5-diazatricyclo[4.2.1.0^{3,7}]nonan-4,5-dicarboximide (**6**): Into a 25-ml, three-necked, round-bottomed flask, provided with spinbar and nitrogen gas inlet and outlet, were placed 159 mg (0.510 mmol) of ene-product **2**, 149 mg (1.12 mmol) of $AlCl_3$, and 7 ml of dry CH_2Cl_2. The reaction mixture was stirred under nitrogen for 24 h at ca. 20 °C and 10 ml of 10% aqueous NaOH was added. The CH_2Cl_2-layer was separated, the aqueous layer extracted with ether (2 × 10 ml), and the combined organic layers washed with a saturated, aqueous NaCl solution (1 × 10 ml), and dried over $MgSO_4$. Roto-evaporation of the solvent at ca. 10 – 15 Torr afforded 124 mg (78%) of urazole **6**, colorless needles, m. p. 104 – 105 °C (from ethanol). – IR ($CDCl_3$): 3060, 3040, 2960, 2920, 2880, 1765, 1719, 1600, 1500, 1420, 1300, 1130, 1790 cm^{-1}. – ^1H NMR ($CDCl_3$) at 400 MHz: δ = 1.01 (s; 3H, 8-CH_3), 1.15 (s; 3H, 8-CH_3), 1.16 (dd, *J* = 14.0, 1.4 Hz; 1H, 9-*endo*-H), 1.66 (d, *J* = 14.5 Hz; 1H, 2-*endo*-H), 1.81 (s; 3H, 3-CH_3), 1.89 (ddd, *J* = 4.0, 3.5, 1.3 Hz; 1H, 1-H), 2.28 (ddd, *J* = 14.5, 4.0, 3.5 Hz; 1H, 2-*exo*-H), 2.44 (dddd, *J* = 14.0, 8.2, 3.5, 3.5 Hz; 1H, 9-*exo*-H), 2.49 (dd, *J* = 4.5, 1.3 Hz; 1H, 7-H), 4.52 (ddd, *J* = 8.2, 4.5, 1.4 Hz; 1H, 6-H), 7.26 – 7.34 (m; 1H, *para*-aromatic H), 7.39 – 7.46 (m; 2H, *meta*-aromatic H), 7.48 – 7.54 (m; 2H, *ortho*-aromatic H). – ^{13}C NMR ($CDCl_3$) at 100 MHz: δ = 21.30 (q; *exo*-8-CH_3), 23.20 (q; *endo*-8-CH_3), 24.75 (q; 3-CH_3), 35.71 (t; C-9), 43.41 (t; C-2), 43.56 (d; C-1), 46.97 (s; C-8), 57.23 (d; C-7), 64.19 (d; C-6), 67.24 (s; C-3), 125.35 (d; C-*ortho*), 127.78 (d; C-*para*), 128.94 (d; C-*meta*), 132.13 (s; C-α), 151.30 (s; C=O), 152.48 (s; C=O). – MS (70 eV): *m/e* = 312 (21%, $M^+ + 1$), 311 (100, M^+), 135 (26), 119 (32, M – PhNCO), 108 (74), 93 (66).

$C_{18}H_{21}N_3O_2$ (311.4) Calcd. C 69.43 H 6.80 N 13.50 Found C 69.48 H 6.84 N 13.41

[1] *W. Adam, O. De Lucchi,* and *K. Hill,* Chem. Ber. **115**, 1982 (1982).
[2] *W. Adam* and *W. D. Gillaspey,* Tetrahedron Lett. **1983**, 1699.
[3] For a discussion of W-coupling, cf. *A. P. Marchand,* „Stereochemical Applications of NMR Studies in Rigid Bicyclic Systems", pp. 174 – 193, Verlag Chemie International, Deerfield Beach, Florida, 1982.
[4] *J. A. Berson,* in „Molecular Rearrangements", *P. de Mayo* (ed.), Vol. 1, Chapter 3, Interscience Publishers, New York 1964.

[329/83]