Tetrahedron Letters No. 45, pp 4367 - 4370. 0040-4039/79/1101-4367$02.00/0

CYCLOADDITION OF 4-PHENYL-1,2,4-TRIAZOLINE-3,5-DIONE (PTAD) TO BICYCLOALKENES VIA REARRANGEMENT OF ZWITTERIONIC INTERMEDIATES

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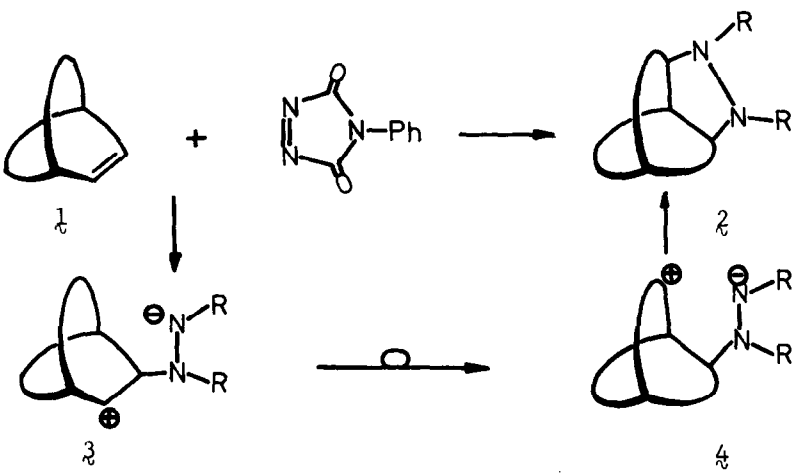
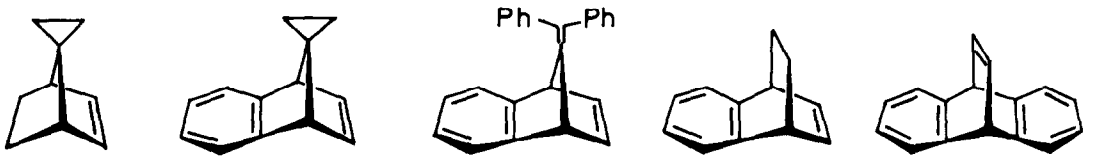
Summary: The formation of tricyclic urazoles between PTAD and bicyclic olefins via rearrangement of the intermediary 1,4-dipoles appears to be general, including moderately strained, benzo-annulated, and functionalized substrates.

In view of the synthetic utility and mechanistic importance of cyclic azo compounds,[2] it was of interest to explore the scope of our recently reported[3] cycloaddition of PTAD with strained bicycloalkanes 1 leading to tricyclic urazoles 2 (eq. 1). The latter serve as convenient precursors to the desired tricyclic azo

(eq. 1)



compounds. A key feature of the proposed mechanism is attack by PTAD resulting initially a 1,4-dipolar intermediate 3 capable of skeletal rearrangement to the ultimate zwitterion 4, which subsequently collapses to the tricyclic urazole product 2. To examine the generality of this intriguing transformation, we employed bicycloalkenes such as the functionalized substrates 1a, 1b, and 1c in order to assess whether the respective rearranged 1,4-dipolar intermediates 4 could be side-



1a 1b 1c 1d 1e

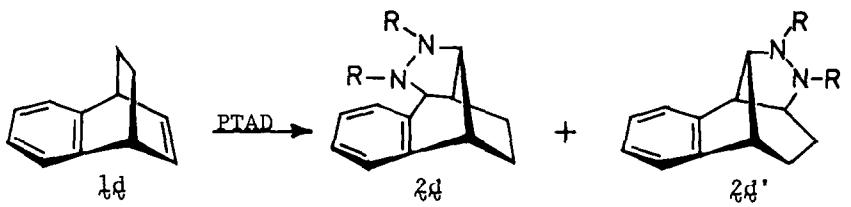
tracked into more deep-seated transformations involving the cyclopropyl group in the case of 1a and 1b and the benzhydrylidene group in the case of 1c. The moderately strained substrates 1d and bicyclo(2.2.2)oct-2-ene and the dibenzo-annulated substrate 1e were chosen to explore whether PTAD is still capable of generating the corresponding initial 1,4-dipoles 3.

On reflux of the bicycloalkenes 1 with excess PTAD, all but bicyclo(2.2.2)oct-2-ene afforded the expected tricyclic urazoles 2 in moderate to good yields. The urazoles 2 were isolated and purified by successive roto-evaporation of the solvent, silica gel chromatography with CH_2Cl_2 as eluant, and recrystallization from methanol. The reaction conditions, yields, and physical constants are summarized in Table I. The following spectral data were decisive in assigning the proposed tricyclic urazole structures. Thus, the IR spectra ($CDCl_3$) all showed the characteristic urazole double C=O bands at 1775 and 1720 cm^{-1} and the ^{1}H-NMR spectra ($CDCl_3$, TMS) exhibited resonances at δ(ppm): 2a: 0.5-1.3 (4H, m, cyclopropyl), 1.65 (4H, m, methylenic), 2.07 (1H, m, H_4), 2.80 (1H, m, H_2), 3.68 (1H, m, H_1), 4.25 (1H, m, H_3) and 7.15 (5H, b.s., phenyl); 2b: 0.1-1.5 (4H, m, cyclopropyl), 2.94 (1H, m, H_4), 3.80 (2H, b.s., H_1 and H_2), 4.57 (1H, m, H_3), 6.6-7.2 (4H, m, benzo-ring), and 7.17 (5H, b.s., phenyl); 2c: 3.78 (1H, m, H_3), 4.18 (1H, m, H_2), 4.70 (1H, m, H_1), 5.07 (1H, m, H_4), 7.00 (14H, m, benzo-ring and benzhydryl phenyls), and 7.25 (5H, b.s., N-phenyl); 2d: 1.50-2.10 (4H, m, methylenic), 3.45 (1H, m, H_4), 3.70 (1H, m, H_2),

4.45 (1H, dd, J = 4.3 Hz, 6.7 Hz, H_3), 4.90 (1H, d, J = 5 Hz, H_1), 6.7-7.45 (4H, m, benzo-ring), and 7.18 (5H, b.s., phenyl); 2e: 4.39 (2H, m, H_1 and H_3), 4.81-5.12 (2H, m, H_2 and H_4), 6.5-7.2 (8H, m, benzo-ring), and 6.9 (5H, b.s., phenyl). Double resonance experiments of the bridge-head protons H_{1-4} were particularly valuable in making these assignments.[4]

For the PTAD adduct 1d structures 2d and 2d' are possible (eq. 2), formed respectively from endo and exo attack by PTAD and subsequent rearrangement of the resulting dipolar intermediates by respective alkyl (dimethylene bridge) and aryl (benzo bridge) migration. The ^{1}H-NMR of the cycloadduct is consistent with the endo attack structure 2d since the bridge-head hydrogens at C_1 and C_3 are respectively

(eq. 2)



1d 2d 2d'

a doublet and a doublet of doublets. Decoupling experiments confirmed this assignment; however, an X-ray structure determination is underway for rigorous confirmation.

From the spectral data and the results of Table I we conclude that:

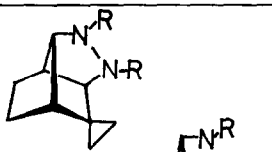
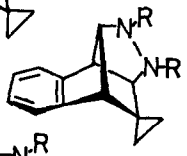
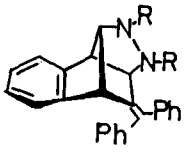
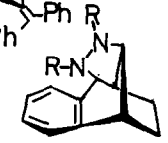
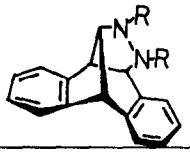
(i) PTAD leads to the expected urazoles even for the functionalized bicycloalkenes 1a-c without participation of the cyclopropyl and benzhydrylidene moieties.

(ii) PTAD fails to react with bicyclo(2.2.2)oct-2-ene even after two weeks of reflux in a polar solvent such as CH_3CN, but is at its threshhold of cycloadditive capability for the moderately strained bicycloalkene 1d.

(iii) PTAD cycloadds to benzo-annulated substrates such as 1d and 1e in which rearrangement of the initial 1,4-dipolar adduct to the benzyl cation-stabilized ultimate zwitterion serves as driving force.

Our results suggest that the unusual dipolar rearrangement is quite general and should be helpful in the choice of other bicycloalkene substrates[5,6] to design the essential tricyclic urazoles for synthetic utilization and mechanistic exploration. Work is in progress for converting the urazoles 2 to their respective tricyclic azoalkanes to examine their thermal and photochemical behavior.

TABLE I: Urazoles 2 Formed in the Reaction of Bicycloalkene 1 with PTAD.

Urazole[a]		Solvent	Moles PTAD[b]	Time (h)	Temp. (°C)	Yield (°C)	mp[c] (°C)
	2a	$CDCl_3$	2	48	30	70	184
	2b	CD_3CN	4	48	40	70	158-159
	2c	CH_2Cl_2	2	12	30	31	183-184
	2d	CH_2Cl_2	10	240	80	17	180
	2e	CD_3CN	10	16	80	63	243-245

a. R+R= Ph-N<CO-CO-

b. Per mole of bicycloalkene 1.

c. All urazoles 2 gave satisfactory elemental composition on combustion analysis.

ACKNOWLEDGEMENTS are made to the Donors of the Petroleum Research Fund (11022-AC1), administered by the American Chemical Society, the National Science Foundation (CHE-78-12621), and the National Institutes of Health (GM-00141-04 and RR-8102-07) for their financial support.

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   b) H. Dürr and B. Ruge, Topics in Current Chemistry, 66, 53 (1976).
3. W. Adam, O. De Lucchi, and I. Erden, Angew. Chem., 91, 512 (1979).
4. In these assignments the protons H_{1-4} refer to the traditional numbering of the ring skeleton of the original bicycloalkene 1 from which the urazoles are derived.
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(Received in USA 3 July 1979)