Synthesis of Urazoles *via* Cycloaddition Employing 4-Phenyl-4*H*-1,2,4-Triazole-3,5-dione (PTAD) Transfer

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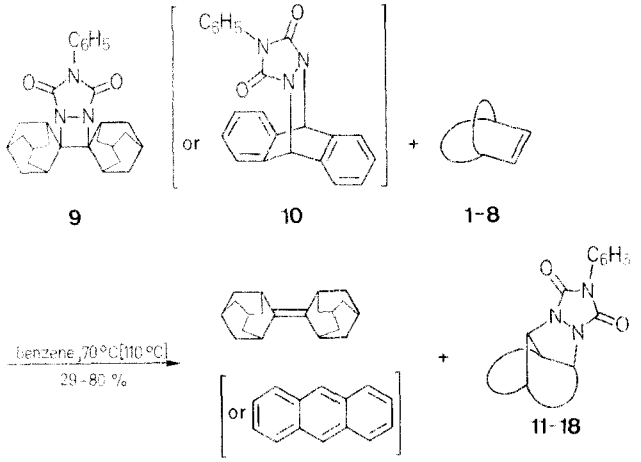
A new method was developed involving transfer of 4-phenyl-4*H*-1,2,4-triazole-3,5-dione (PTAD) from thermally labile urazoles **9** and **10** to bicyclic olefin derivatives **1–8**, which irreversibly undergo cycloaddition accompanied by Wagner-Meerwein rearrangement. In most cases purer products and significantly improved yields of the corresponding urazoles **11–18** are obtained than by direct PTAD cycloaddition.

To this day 4-phenyl-4*H*-1,2,4-triazole-3,5-dione[1a–c] is still being used extensively in cycloaddition reactions, either because the resulting urazoles serve as convenient sources for desired azo compounds or because the mechanistic details of the PTAD reaction with olefins[2a–c] are under examination. Of the numerous possible cycloaddition modes of PTAD ($[4\pi + 2\pi]$, $[2\pi + 2\pi]$, ene, $[2\sigma + 2\pi]$), the reaction with olefins involving Wagner-Meerwein rearrangement has notoriously given low yields (below 30%)[1a–d]. A further disadvantage is the fact that PTAD has to be used in ca. three-fold excess with respect to the olefin[1a], due to its extensive degradation at elevated temperatures[3].

To circumvent these preparative problems, we decided to exploit the fact that urazole **9** conveniently cleaves *via* [2+2]-retrocyclization into PTAD and adamantylideneadamantane at ca. 70 °C.[4] This should enable the releasing of controlled amounts of PTAD at the temperatures required for cycloaddition with the substrate, but avoiding undesired competing side reactions of PTAD. Similarly, urazole **10** could be employed at higher temperatures, affording PTAD *in situ* at ca. 110–140 °C by a [4+2]-retrocyclization. Here we report the use of the PTAD donors **9** and **10** in the conversion of the olefins **1–8** to their respective cycloadducts with PTAD.



Adamantylideneadamantane was prepared from adamantanone by the McMurry reaction. Urazoles **9** and **10** were obtained quantitatively by reaction of adamantylideneadamantane or anthracene, respectively, with PTAD at 20 °C[4]. For the synthesis of the olefins **1–8** and of authentic samples of the respective urazoles known literature procedures were used[1a–d].

The results of the PTAD transfer reactions of the urazoles **9** and **10** with olefins **1–8** are collected in the Table.

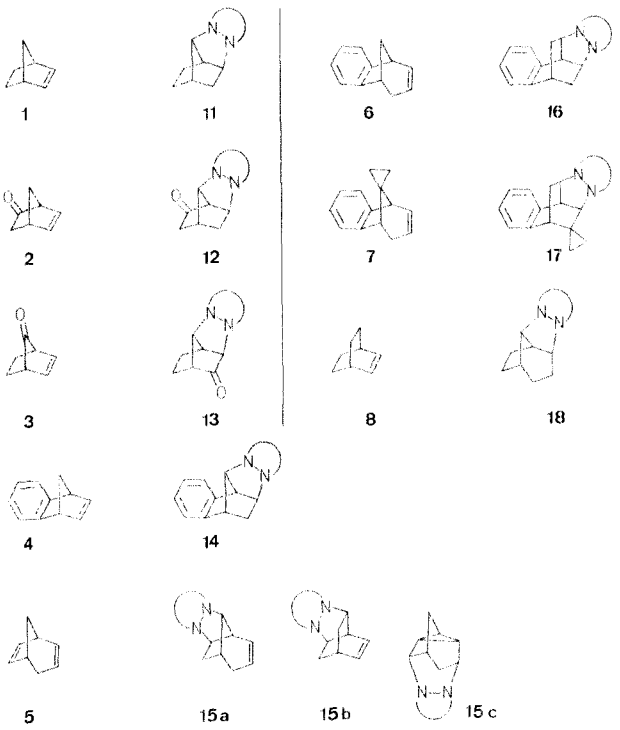


Table. Transfer Reactions of Olefins **1–8** with the PTAD Donors **9** and **10**

Olefin	Urazole	Isolated Yields (%) **9** (80 °C)[a]	**10** (110 °C)[b]	**10** (140 °C)[c]	**PTAD**[d,f] (ca. 40–50 °C)	Ref.
1[e]	**11**	48	–	22	47	1a
2	**12**	18	29	–	7 (9)	1b
4	**14**	80	–	28	76	1a
5	**15a**	50	15	–	33 (20)	5
	15b	6	5	–	11 (6)	5
	15c	8	1	–	39 (18)	5
6	**16**	68	50	24	31 (31)	1a
7	**17**	33	–	–	10	this work

[a] refluxing benzene: 100% consumption of urazole **9** in 80–120 h.
[b] refluxing toluene: 20–40% consumption of urazole **10** in 300–500 h
[c] refluxing 1,1,2,2-tetrachlorethane: 60–80% consumption of urazole **10** in 150–250 h
[d] ca. three-fold excess of PTAD was used relative to olefin in the direct addition
[e] olefin **1** was used in 2.5-fold excess
[f] yields in parenthesis refer to this work and were for olefin **5** consistently lower than those reported (Ref. 5); the discrepancy appears to be due to varying amounts of on-column decomposition during the chromatographic purification of the urazole product, depending on the type of silica gel used (in this work: 60–230 mesh, Merck, activity 1).

In most cases the yields of the urazole products could be improved significantly using the PTAD donors **9** and **10**. For both donors maximum yields were achieved when a 1:1 ratio of **9** or **10** to the olefins was used. The best results were obtained with **9**, although **10** gave a better yield (29% versus 18%) in the case of olefin **2**. At 140°C urazole **10** gave mainly black tar with olefin **2**, whereas at 110°C only little decomposition of released PTAD was noted. With urazole **9** on the other hand the PTAD transfer was quite clean at 80°C, especially when compared to the direct use of PTAD (sixth column in the Table). In all cases, donor **9** gave 10–20 times faster reaction at 80°C than **10** at 110°C. After consumption of the PTAD donors, ca. 95% of the adamantylideneadamantane or anthracene could be recovered by chromatography on silica gel and recycled without further purification. The most effective use of the PTAD donor **9** was mixing equimolar portions of adamantylideneadamantane, PTAD and the respective olefin in benzene and stirring at ca. 20°C for about 2 h, whereby urazole **9** is produced quantitatively. Subsequently, the PTAD was slowly released *in situ* by heating the solution to 80°C, at which temperature it is transferred to the substrate.

Unfortunately, as in the case of direct reaction with PTAD, olefins **3** and **8** where inert towards the PTAD donors **9** or **10** under all conditions tried. In these attempts adamantylideneadamantane or anthracene and the respective olefin could be recovered essentially quantitatively, whereas PTAD deteriorated into a complex mixture of products[3].

On the basis of the present results the PTAD donor 9 is the preferred reagent in most cases for preparative transfer of PTAD to olefins, because:

- the deterioration of PTAD is minimized, thus affording improved yields of rearranged urazoles;
- stoichiometric amounts of the PTAD donor **9** can be used;
- cycloaddition products are formed with fewer by-products;
- the preparation of PTAD carrier **9** is convenient, fast and quantitative;
- more than 95% of the released adamantylideneadamantane can be recovered and recycled; and
- the PTAD donor has a good shelf life – it can be stored for several months at 20–25°C.

Melting points are uncorrected and were measured in sealed capillaries on a Büchi SMP-20 apparatus. Infrared spectra were recorded on a Beckman Acculab 4 spectrometer, ^{1}H-NMR spectra (90 MHz) were measured on a Varian EM 390 and ^{13}C-NMR spectra (100 MHz) on a Bruker WM-400 NMR spectrometer. Mass spectra were recorded on a Varian MAT CH7.

Transfer of 4-Phenyl-4*H*-1,2,4-triazole-3,5-dione with Urazole 9; General Procedure:

A mixture of PTAD (3.50 g, 20.0 mmol) adamantylideneadamantane (5.36 g, 20.0 mmol) and the respective olefin (20.0 mmol) in benzene (50 ml) is stirred for 2 h at ca. 20°C. The solution is then refluxed for 100 h, allowed to cool to ca. 20°C and the adamantylideneadamantane and the urazole are separated by means of column chromatography on silica gel (ca. 50 g) using dichloromethane as eluent. The isolated urazoles could be used without further purification.

8,9-Benzo-4,5-diazaspiro[tricyclo[4.3.1.0^{3,7}]dec-8-ene-2,1′-cyclopropane]-4,5-dicarboximide (17):

From 6,7-benzospiro[bicyclo[3.2.1]octa-2,6-diene-8,1′-cyclopropane] (**7**) (3.00 g, 16.5 mmol), adamantylideneadamantane (4.42 g, 16.5 mmol) and PTAD (2.88 g, 16.5 mmol) urazole **17** was obtained; yield: 1.94 g (33%); m.p. 166°C, colorless powder (ethanol).

IR (CCl_4): ν = 3070, 3400, 3020, 3000, 2940, 2850, 1765, 1710, 1500 1410 cm^{-1}.

^{1}H-NMR ($CDCl_3$): δ = 0.3–1.2 (m, 4H, 2′-H, 3′-H), 1.6–2.2 (m, 3H, 1-H, 10-H), 3.51 (t, 1H, 7-H), 3.79 (d, J = 4.5 Hz, 1H, 3-H), 4.42 (dd, J_1 = 5.4, J_2 = 8.7 Hz, 1H, 6-H), 6.9–7.6 (m, 9H$_{arom}$).

^{13}C-NMR ($CDCl_3$): δ = 10.51 (t, cyclopropyl-C), 15.90 (t, cyclopropyl-C), 26.64 (s, C-2), 34.27 (t, C-10), 42.05 (d, C-1), 47.71 (d, C-7), 55.86 (d, C-3), 64.91 (d, C-6), 123.01 (d, aryl-C), 125.47 (d, aryl-C), 126.81 (d, aryl-C), 127.97 (d, aryl-C), 129.15 (d, aryl-C), 131.82 (s, aryl-C), 132.16 (s, C-8), 144.61 (s, C-9), 155.36 (s, carbonyl-C), 155.64 (s, carbonyl-C).

MS (70 eV): m/e = 358 (5%, M$^+$), 357 (20%), 180 (11%), 155 (100%), 128 (13%).

$C_{22}H_{19}N_3O_2$	calc.	C 73.99	H 5.36	N 11.76
(357.4)	found	73.99	5.34	11.59

Conventional Preparation of Urazole 17:

A solution of olefin **7** (3.00 g, 16.5 mmol) and PTAD (4.32 g, 24.7 mmol) in dichloromethane (100 ml) is refluxed for 72 h. After cooling to ca. 20°C and evaporation of the solvent (20°C, 20 Torr), the product is purified by column chromatography on silica gel (50 g) using dichloromethane as eluent; yield: 594 mg (10%); m.p. 166°C, colorless powder (ethanol).

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