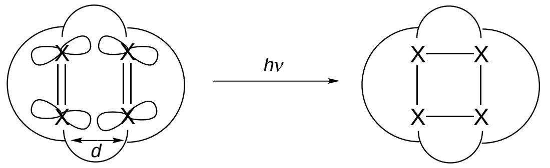
Highly efficient photometathesis in a proximate, synperiplanar diazene-diazene oxide substrate: retention of optical purity, mechanistic implications

Kai Exner and Horst Prinzbach*†

Institut für Organische Chemie und Biochemie, Universität Freiburg, Albertstr. 21, D-79104 Freiburg, Germany

In a specifically designed proximate and almost perfectly synperiplanar diazene–diazene oxide substrate, metathesis is the exclusive photoreaction and occurs with retention of optical purity, providing support for the [π2 + π2]photocycloaddition pathway (tetrazetidine oxide intermediate).

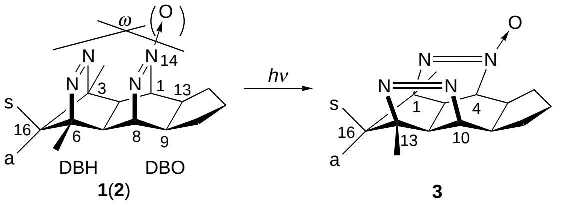
An intriguing discrepancy between rigid, proximate (*d*), synperiplanar (*ω*) dienes **A** (X = CR) and bisdiazenes **A** (X = N) is the contrasting propensity for [π2 + π2] photocycloaddition (**A** → **B**).[1] The ease of N_2 extrusion is the main reason for the repeated failure to achieve diazene + diazene → tetrazetidine photocycloaddition [reaction (1)].[2,3]



A **B**

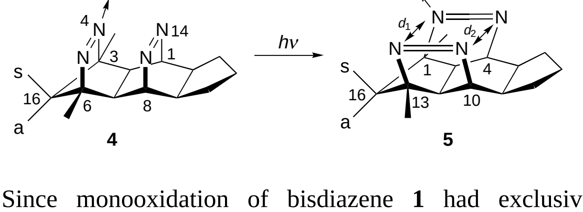
(1)

We have recently reported that in the specifically designed very proximate and nearly synperiplanar bisdiazene **1** with its very favourable stereoelectronic prerequisites (d = 2.822 Å, ω = 174.2°, X-ray), N_2 elimination still precludes the [π2 + π2] photocycloaddition, but that some photometathesis of its oxide **2** (→ **3**) does occur (2%) [reaction (2)], most probably through the tetrazetidine oxide.[4] Given the quantum yields $\Phi_{\text{-N}_2}$ of 1.00 and 0.02, respectively, for the N_2 elimination from the parent 2,3-diazabicyclohept-2-ene (DBH) and 2,3-diazabicyclooct-2-ene (DBO),[5] the cycloaddition (metathesis) of the isomeric oxide **4** with its oxidized DBH- and 'reluctant' DBO-subunits was expected to be more successful [reaction (3)]. The synthesis of **4** as a racemate and as the (+)-enantiomer and the experimental verification of the above hypotheses are the subjects of this communication.[6]



1(**2**) **3**

(2)

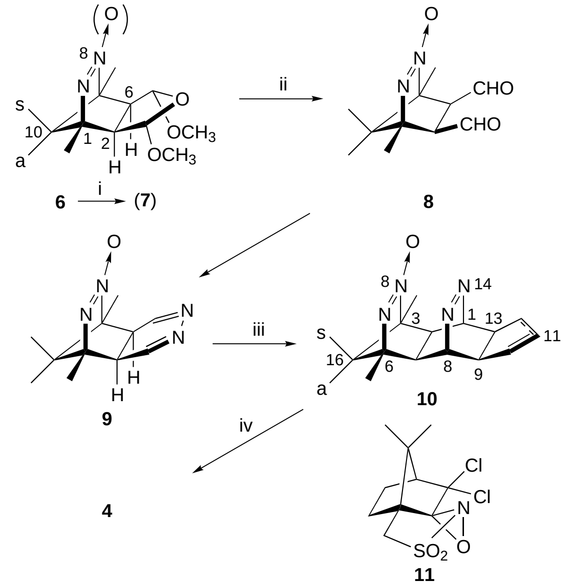


4 **5**

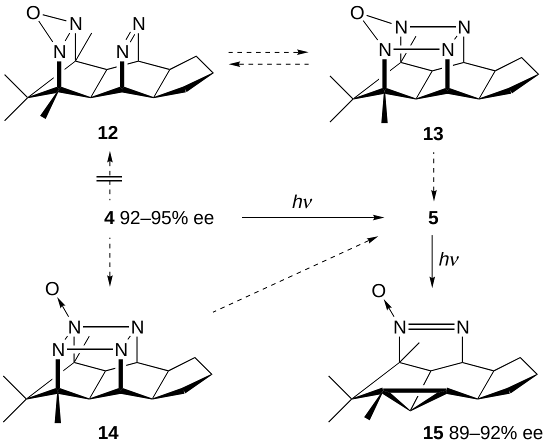
(3)

Since monooxidation of bisdiazene **1** had exclusively occurred in the DBO section to give **2**, the isomer **4** was prepared starting with **6**[4] (Scheme 1). The quantitatively obtained oxide *rac*-**7** [$\lambda_{\max}$ (CH_3CN)/nm 230 (ε/dm^3 mol^{-1} cm^{-1} 5980)] was then transformed into the diazene-diazene oxide **10** (mixture of diastereomers [$\lambda_{\max}$ (CH_3CN)/nm 236 (ε 3340), 387 (82)] *via* dialdehyde **8** and dihydropyridazine **9** (mixture of trimers) following the procedure for the preparation of **1**. Yet, hydrogenation (catalytic, N_2H_2) of the cyclopentene ring in **10** could not be effected without partial deoxygenation (→ **1**). Typical for the rigid, colourless, crystalline *rac*-**4**, obtained in *ca.* 50% yield after chromatography and crystallisation ($CHCl_3$–*n*-hexane), are *inter alia* the small H,H coupling constants ($J_{1,2\,(1,13)}$ = $J_{7,8\,(8,9)}$ = 1.6 Hz) and the m/z = 141 fragment in the EIMS spectrum (3,4,4,5-tetramethyl-4*H*-pyrazole 1-oxide + H$^+$, 100%). In the UV spectra (CH_3CN) of **10** (**4**) the distinct N=NO π,π* maxima at 237(236) nm [ε 3780(2340)] and the N=N n,π* maxima at 387(387) nm [ε 82(81)], when compared with the N=NO absorption of **7** and the n,π* maximum for the parent DBO [$\lambda_{\max}$(*n*-hexane)/nm 378 (ε 182)], can be taken as evidence for a weak transannular N=N/N=NO interaction. Note that **2** and **4**, upon heating to their melting temperature (260/264 °C), remained unchanged; there was no indication for their interconversion or for their common [4 + 2] oxazolidine cycloadduct;[7] at even higher temperatures neat N_2 elimination (**2**) or oligomerization (**4**) occurred.

In line with expectation n,π* excitation (solidex vessel, CH_3OH, 150 W Hg high pressure lamp, 25 °C) for several hours left **4** unchanged; denitrogenation was obviously very much slower than in isomer **2**. Monochromatic π,π* excitation (254 nm, quartz vessel, CH_3OH, Hanau TNN 15 lamp, 25 °C)



Scheme 1 *Reagents and conditions*: i, (±)-**7**: DMDO, CH_2Cl_2–Me_2CO, rt, quant.; (+)-**7**: (+)-**11**, 14 kbar, 65 °C, 12 d, ethyl acetate, 75%, 92–95% ee; ii, 1 M H_2SO_4, reflux, used as CH_2Cl_2 solution of the hydrate; N_2H_4, 10 equiv., K_2CO_3, 100 equiv. CH_2Cl_2, 0 °C; iii, TFA (1 equiv.), cyclopentadiene (*ca.* 500 equiv.), CH_2Cl_2, 4 °C, 62%; iv, H_2/MeOH/Pd/C (10%), rt, 66%



Scheme 2 Photochemistry of (chiral) bisdiazene oxide **4** and its isomer **5** (254 nm low pressure Hg lamp, MeOH, rt)

generated, in up to *ca.* 10% conversion exclusively, the metathesis isomer **5** (TLC, NMR) which was chromatographically isolated as colourless crystals [λ_{max} (CH_3CN)/nm 239 (ε 5510, π,π* N=NO), 346 (ε 172, n,π* N=N)]. With increasing conversion, denitrogenation of **5** to give **15** (70–75% was isolated in the crystalline form) and oligomers (25–30%) became important (Scheme 2). By separate irradiation of **5** it was ascertained that **15** indeed was a secondary photoproduct. The skeletal changes in going from **4** to the more mobile **5** with the most stable calculated (B3LYP/6-31G*) conformation at d_1 = 3.142 and d_2 = 2.950 Å (ω = 161.4°) are manifested *inter alia* by the relatively large H,H coupling constants $J_{4,5}$ = 5.9, $J_{4,15}$ = 6.4, $J_{9,10}$ = 9.2, $J_{10,14}$ = 7.0 Hz and the hypsochromic displacement of the N=N n,π* absorption.[8]

Of the two pathways shown in Scheme 2 for the metathesis **4** → **5**, the route featuring the C_s symmetrical **12** and **13** as intermediates could be put to experimental test with optically active **4**. After futile attempts to oxidize **6** enantioselectively using Sharpless[9] and Jacobsen[10] methods, with percamphanic acid[11] or the chiral oxaziridine **11**,[12] the application of high pressure to the reaction of **6** with **11** brought the solution: chiral oxide **7** was isolated with 92–95% ee (Chiralcel AD, propan-2-ol–*n*-hexane 1:3). After standard synthesis of (+)-**4** and photolysis, the retention of the optical purity was established for (−)-**15** (89–92% ee, Chiralcel AD, the enantiomers of **4** and **5** could not be sufficiently separated). Experiments for the low-temperature (matrix) characterisation of the tetrazetidine oxide **14** as the most plausible intermediate are in progress.[13]

This work was supported by the Deutsche Forschungsgemeinschaft, the Fonds der Chemischen Industrie, and BASF AG. We thank B. Geiser for technical assistance.

Notes and References

† E-mail: prinzbach@oca.chemie.uni-freiburg.de

1 Another fundamental difference is the readiness of these ‘proximate’ bisdiazenes to undergo one- and two-electron reduction with generation of so far unknown cyclically delocalised, highly persistent 4N/5e radical anions and 4N/6e dianions. K. Exner, O. Cullmann, D. Hunkler, H. Prinzbach, G. Gescheidt and V. Peron, unpublished results.

2 H. Prinzbach, G. Fischer, G. Rihs, G. Sedelmeier, E. Heilbronner and Z.-Z. Yang, *Tetrahedron Lett.*, 1982, **23**, 1251, *c.f.* E. Tauer and R. Machinek, *Liebigs Ann. Chem.*, 1996, 1213; E. Tauer, K.-H. Grellmann and A. Heinrich, *Chem. Ber.*, 1991, **124**, 2053; G. Ritter, G. Häfelinger, H. Rau and E. Lüdecke, *J. Am. Chem. Soc.*, 1989, **111**, 4627.

3 E. Beckmann, N. Bahr and H. Prinzbach, *Tetrahedron Lett.*, 1990, **31**, 1125.

4 K. Exner, D. Hochstrate, M. Keller, F.-G. Klärner and H. Prinzbach, *Angew. Chem., Int. Ed. Engl.*, 1996, **35**, 2256.

5 P. S. Engel, *Chem. Rev.*, 1980, **80**, 99; M. A. Anderson and C. B. Grissom, *J. Am. Chem. Soc.*, 1995, **117**, 5041 and references therein.

6 All compounds have been fully characterized (^1H, ^{13}C NMR, MS, UV, IR). *Selected data* for **4**: δ_H($CDCl_3$, 400 MHz) 5.47 (dd, $J_{7,8}$ = $J_{8,9}$ 1.6, 8-H), 5.31 (dd, $J_{1,2}$ = $J_{1,13}$ 1.6, 1-H), 2.35 (*A*BXY, J_{AB} 10.4, 7-H), 2.27 (A*B*XY, J_{AB} = 10.4, 2-H), 2.32–2.25 (dddd, 9-H), 2.23–2.15 (dddd, 13-H), 1.80–1.70 (m, 10a-H, 12a-H), 1.47 (s, 6-Me), 1.45–1.35 (m, 10s-H, 11a-H, 12s-H), 1.39 (s, 3-Me), 1.23–1.10 (m, 11s-H), 0.92 (s, 16s-Me), 0.72 (s, 16a-Me); δ_C($CDCl_3$, 100.6 MHz) 91.0 (C-3), 75.6 (C-6), 64.0 (C-8), 63.6 (C-1), 59.8 (C-16), 48.3 (C-7), 44.6 (C-13), 43.7 (C-9), 43.3 (C-2), 30.2/29.9 (C-10, C-12), 26.2 (C-11), 17.4 (16-Me *anti*), 15.6 (16-Me *syn*), 12.1 (6-Me), 9.7 (3-Me); *m*/*z* (EI) 201 [$M^+ - Me - N_2 - N_2O$] (5%), 141 [tetramethyl-4*H*-pyrazole *N*-oxide + H^+] (100), 125 [tetramethyl-4*H*-pyrazole + H^+] (26), 91 (39); λ_{max}(CH_3CN)/nm 204 (ε/dm^3 mol^{-1} cm^{-1} 4620), 237 (3780), 387 (81). ν (KBr)/cm^{-1} 1509 (NNO). *Selected data* for **5**: δ_H($CDCl_3$, 400 MHz) 4.38 (dd, $J_{9,10}$ 9.2, $J_{10,14}$ 7.0, 10-H), 4.10 (dd, $J_{4,5}$ 5.9, $J_{4,15}$ 6.4, 4-H), 2.79–2.69 (dddd, 9-H), 2.58 (dd, $J_{4,15}$ = 6.4, $J_{14,15}$ 10.4, 15-H), 2.45–2.35 (m, i. a. 5-H), 2.25–2.19 (m, 8-H), 2.15 (dd, $J_{10,14}$ = 7.0, $J_{14,15}$ 10.4, 14-H), 2.11–1.96 (m, 2 H), 1.93–1.85 (m, 1 H), 1.84 (s, Me), 1.59–1.48 (m, 7-H), 1.40 (s, Me), 1.05 (s, Me), 1.02 (s, Me): δ_C($CDCl_3$, 100.6 MHz) 105.4 (C-13), 98.5 (C-1), 86.5 (C-10), 65.7 (C-4), 49.3 (C-16), 45.4 (C-15), 41.0 (C-14), 37.2 (C-9), 36.7 (C-5), 31.5/30.1 (C-6, C-8), 26.1 (C-7), 25.2/17.2/16.9/15.0 (CH_3); *m*/*z* (EI) 288 [M^+] (2%), 244 [$M^+ - N_2O$] (1), 216 [$M^+ - N_2 - N_2O$] (28), 201 [$M^+ - N_2 - N_2 O - Me$] (100), 133 (60); λ_{max}(CH_3CN)/nm 239 (ε/dm^3 mol^{-1} cm^{-1} 5510), 346 (172); ν_{max}(KBr)/cm^{-1} 1509 (NNO).

7 For related ene-diazene oxide cycloadditions see, G. Fischer, D. Hunkler and H. Prinzbach, *Tetrahedron Lett.*, 1984, **25**, 2459; S. Hünig and M. Schmitt, *Liebigs Ann. Chem.*, 1995; 1801, and references therein.

8 N. Bahr, E. Beckmann, K. Mathauer, D. Hunkler, M. Keller, H. Prinzbach and H. Vahrenkamp, *Chem. Ber.*, 1993, **126**, 429; O. Cullmann, Ph.D. Dissertation, University of Freiburg, 1998.

9 The modified procedure used to oxidize sulfides to sulfones was applied: P. Pitchen, E. Dunach, M.N. Deshmukh and H.B. Kagan, *J. Am. Chem. Soc.*, 1984, **106**, 8188.

10 E. N. Jacobsen, W. Zhang, A. R. Muci, J. R. Ecker and L. Deng, *J. Am. Chem. Soc.*, 1991, **113**, 7063.

11 F. D. Greene and St. S. Hecht, *Tetrahedron Lett.*, 1969, **18**, 575.

12 F. A. Davis, M. C. Weismiller, C. K. Murphy, R. T. Reddy and B.-C. Chen, *J. Org. Chem.*, 1992, **57**, 7274.

13 Together with M. Schweizer, J. Wirz (Basel), H.-P. Reisenauer and G. Maier (Gießen).

Received in Liverpool, UK, 23rd December 1997; 7/09232F