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Supporting Information (4 pages)

Thermal and Photochemical 1,3-Dipolar Cycloaddition of Fluorenethione *S*-oxide (Sulfine) to the Strained Triple Bond of Cyclooctyne

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Experimenal Section

General. Irradiations were carried out in sealed (rubber stopper, parafilm) NMR tubes in a Rayonet photoreactor equipped with 16 350-nm UV lamps (RPR 3500). ^{1}H- and ^{13}C-NMR spectra were recorded in $CDCl_3$ on a Bruker AC 200 or a AC 250 (^{1}H: 200 MHz or 250 MHz; ^{13}C: 50 MHz or 63 MHz) spectrometer, with $CHCl_3$ as reference standard. The products were identified by comparison with the isolated or authentic materials. For quantitative NMR analysis, the sum of aromatic signals was used as internal standard. IR spectra were recorded on a FT-IR Perkin Elmer 1600 spectrophotometer. HPLC analysis was performed on a Kontron analytical chromatograph equipped with a Eurospher silica-gel column (250 × 4.6 mm) from Knauer and a Tunable Absorbance Detector 430 from Kontron (eluent: 98:2 hexane/MTBE). The products were identified by comparison of the retention times with the

isolated materials. TLC analysis was conducted on precoated silica-gel foils Polygram SIL G/UV254 (40 × 80 mm) from Machery and Nagel. Spots were visualized by UV light and spontaneous decolorization of aqueous potassium permanganate solution. Silica gel (20 – 63 μm, Woelm) was used for flash chromatography.

Materials. Sulfine **1** was obtained by the one-pot reaction of the α-silyl carbanions of fluorene with sulfur dioxide.[8] Cyclooctyne (**2**) was synthesized by bromination of *cis*-cyclooctene and subsequent double dehydrobromination with KO*t*Bu and LDA[9] and stored under nitrogen gas at - 20 °C. Fluorenone was purchased from Aldrich and used without further purification. 9,9'-Dimethoxyfluorene was prepared by acetalization of fluorenone with methyl ortho formate.[10] $CDCl_3$ was filtered over basic alumina (activity grade I) prior to use, methanol was dried by distillation over magnesium and stored over molecular sieves. Other solvents were purified by standard procedures.

General Procedure for the Thermolysis of Sulfine 1 in the Presence of Cyclooctyne in $CDCl_3$ Solution. An NMR tube was charged with a solution of 0.103 to 0.125 mmol of the sulfine **1** and 2.10 to 4.71 equiv. of cyclooctyne (**2**) in 1.0 mL of $CDCl_3$. As bases, K_2CO_3 (0.04 mmol) or NEt_3 (0.02 mmol) were added if necessary. The sealed tube (rubber stopper, parafilm) was placed into an oil bath at 40 °C and after 20 to 88 h of heating submitted to quantitative ^{1}H-NMR analysis to determine the extent of conversion, mass balance and product composition against the sum of the aromatic signals as internal standard. The data are given in Table 1.

General Procedure for the Thermolysis of Sulfine 1 in the Presence of Cyclooctyne in Methanol/Methylene Chloride. An NMR tube was charged with a solution of 0.122 to 0.125 mmol of the sulfine **1** and 4.0 equiv. of cyclooctyne in a 4:1 mixture of methanol and

methylene chloride. The sealed tube (rubber stopper, parafilm) was placed into an oil bath at 50 °C. After 48 h of heating, the solvent was removed (20 °C / 15 mbar), the residue dissolved in $CDCl_3$ and submitted to quantitative ^{1}H-NMR and HPLC analysis to determine the extent of conversion, mass balance and product composition against the sum of the aromatic signals as internal standard. The data are given in Table 2..

General Procedure for the Photolysis of Sulfine 1 in the Presence of Cyclooctyne (2) in $CDCl_3$ Solution. An NMR tube was charged with a solution of 0.126 to 0.127 mmol of the sulfine **1** and 2.01 to 3.55 equiv of cyclooctyne (**2**) in 1.0 ml of $CDCl_3$. The tube was placed into a Rayonet photoreactor and cooled to 5 °C. After 3 h of irradiation, the crude reaction mixture was submitted to quantitative ^{1}H-NMR and HPLC analysis to determine the extent of conversion, mass balance and product composition against the sum of the aromatic signals as internal standard. The data are given in Table 1..

1,2,3,4,5,6,8,9,10,11,12,13-Dodecahydrodicycloocta[1,4]dithiin (3)[11] and 2(9'-Fluoren-ylidene)cyclooctanone (5). A sample of 500 mg (2.36 mmol) of the sulfine **1** and 1.28 g (11.8 mmol) of cyclooctyne (**2**) was dissolved in 17.5 mL of methylene chloride. The mixture was heated to 50 °C for 48 h. Evaporation of the solvent at 20 °C/15 mbar and silica-gel flash chromatography, followed by recrystallization, afforded 175 mg (0.624 mmol, 53%) of dithiin **3** as colorless needles, mp 132-133 °C (from methanol), and 348 mg (1.21 mmol, 51%) of enone **5** as a light yellow solid, mp 60-61 °C (from Et_2O/hexane).

Dithiin 3: R_f (20 : 1 petroleum ether / Et_2O) = 0.65; ^{1}H NMR δ 1.38-1.74 (m, 16 H), 2.41 (t, J = 6 Hz, 8 H); ^{13}C NMR δ 26.0 (t), 29.4 (t), 33.0 (t), 131.4 (s).

Enone 5: R_f (20 : 1 petroleum ether / Et_2O) = 0.15; IR (film) 1684 (C=O); ^{1}H NMR δ 1.54-2.05 (m, 8 H), 2.88 (t, J = 6 Hz, 2 H, 3-H or 8-H), 3.19 (t, J = 6 Hz, 2 H, 8-H or 3-H), 7.13-7.46 (m, 5 H), 7.64-7.79 (m, 2 H), 7.85 (d, J = 7 Hz, 1 H); ^{13}C NMR δ 23.7 (t), 24.0 (t), 26.9

(t), 27.4 (t), 33.9 (t), 44.9 (t), 119.9 (d), 120.1 (d), 124.2 (d), 125.7 (d), 127.3 (d), 127.6 (d), 128.3 (d), 128.5 (d), 131.7 (s), 136.7 (s), 138.1 (s), 140.3 (s), 141.0 (s), 145.9 (s), 216.4 (s, C=O); Anal. Calcd for $C_{21}H_{20}O$: C, 87.46; H, 6.99. Found: C, 87.28; H, 7.09.

Bis(1-cyclooctene) Sulfoxide (9): According to the general procedure, a solution of 500 mg (2.36 mmol) of the sulfine **1** and 1.02 g (9.44 mmol) cyclooctyne was heated in a 4:1 mixture of methanol / methylene chloride. Evaporation of the solvent and silica-gel flash chromatography, followed by recrystallization, yielded 180 mg (0.676 mmol, 29%) of sulfoxide **9** as a light beige solid, mp 56-57 °C (from Et_2O / petroleum ether); R_f (5 : 2 petroleum ether / Et_2O) = 0.30; IR (film) 1056 (S=O); ^{1}H NMR δ 1.30-1.75 (m, 16 H), 2.10-2.45 (m, 8 H), 6.42 (t, J = 8 Hz, 2 H, 2-H); ^{13}C NMR δ 23.0 (t), 25.3 (t), 25.5 (t), 26.1 (t), 27.8 (t), 29.9 (t), 135.4 (d, C-2), 142.4 (s, C-1); Anal. Calcd for $C_{16}H_{26}OS$: C, 72.13; H, 9.84; S, 12.03. Found: C, 72.37; H, 9.67; S, 12.15.

References

(8) Porskamp, P. A. T. W.; van der Leij, M.; Lammerink, B. H. M.; Zwanenburg, B. *Recl. Trav. Chim. Pays-Bas* **1983**, *102*, 400-404.

(9) Brandsma, L.; Verkruijsse, H. D. *Synthesis* **1978**, 290.

(10) Bakthavachalam, V.; Lin, L.-G.; Cherian, X. M.; Czarnik, A. W. *Carbohydr. Res.* **1987**, *170*, 124-136.

(11) Bühl, H.; Timm, U.; Meier, H. *Chem. Ber.* **1979**, *112*, 3728-3736.