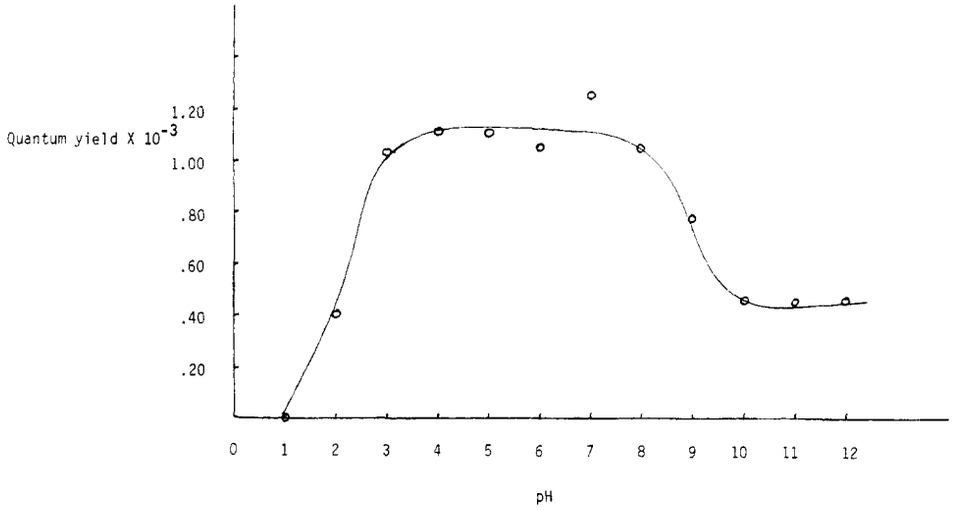
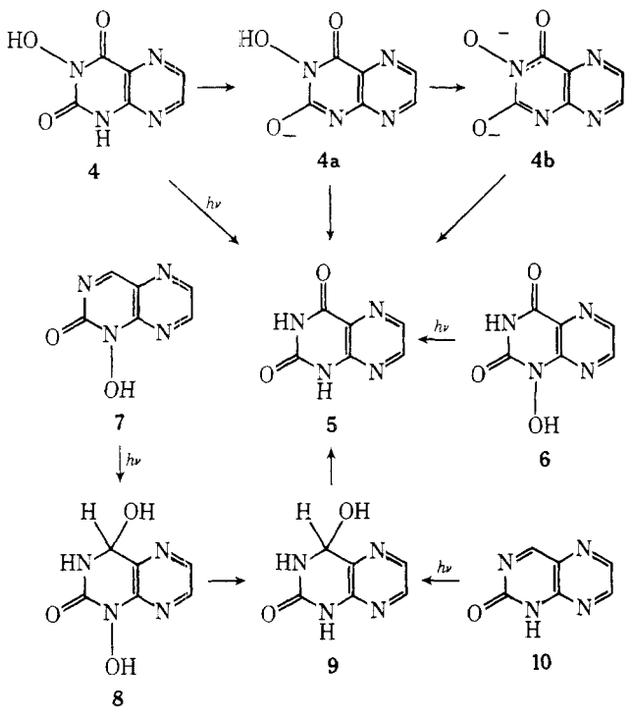


Figure 1. Effect of pH on quantum yields of formation of 2,4-dioxo-1,2,3,4-tetrahydropteridine from 3-hydroxy-2,4-dioxo-1,2,3,4-tetrahydropteridine.

Scheme II



perimental conditions without irradiation. Hence, this represents a novel photochemical oxidation that has not been previously described for pteridines.

Experimental Section

Photolysis. Method A. A sample of compound (~1.0 mmol) was dissolved in 350 mL of H_2O or buffer solution. The solution was degassed and irradiated in an immersion-type apparatus equipped with a 450-W Hanovia high-pressure Hg lamp with a pyrex or corex filter. The disappearance of the starting material was monitored by change in the UV absorption. After the photolysis was discontinued, the solution was then reduced to a small volume in vacuo. The products were then separated and isolated by chromatography over a Bio-Rad AG-50 × 8 (H^+), 200–400 mesh column (9 × 450 mm). Yields of reaction products were calculated from their known ϵ_{max}.

Method B. The quantum-yield study was performed in a Rayonet photochemical reactor equipped with 2537 A and 3000 A and a merry-go-round apparatus. Potassium ferrioxalate was used as the chemical actinometer.[16]

Chromatography. For routine quantitation, a 2.0 × 1000 mm analytical high-pressure liquid chromatography column of Bio-Rad A-6 resin eluted with 0.4 M NH_4OOCH buffer of pH 4.7 and a Laboratory Data Control (LDC) UV monitor were used. The volume values (mL) of compounds **4**, **6**, **5**, **7**, and **10** were found to be 10.5, 10.1, 11.1, 8.0, and 9.0, respectively. The column's temperature was maintained at 50 °C with a flow rate of 16.6 mL/h.

Acknowledgment. We are indebted to Dr. L. Bauer for a sample of **4** and thank Drs. J. C. Parham and G. B. Brown for their continued interest and discussions, and Ms. M. A. Templeton for assistance with the pK_a determination.

Registry No.—**4**, 10579-28-9; **5**, 487-21-8; **7**, 37440-31-6.

References and Notes

(1) This investigation was supported in part by funds from the United States Energy Research and Development Administration, Contract No. E(11-1)-2931, and by Public Health Service Research Grants CA 15274, CA 17085, and CA 08748 from the National Cancer Institute.
(2) G. G. Spence, E. C. Taylor, and O. Buchardt, *Chem. Rev.*, **70**, 231 (1970).
(3) G. B. Brown, G. Levin, and S. Murphy, *Biochemistry*, **3**, 880 (1964).
(4) A. Giner-Sorolla, C. Gryte, M. L. Cox, and J. C. Parham, *J. Org. Chem.*, **36**, 1228 (1971).
(5) F. L. Lam and J. C. Parham, *J. Org. Chem.*, **38**, 2397 (1973).
(6) F. L. Lam and J. C. Parham, *J. Am. Chem. Soc.*, **97**, 2839 (1975).
(7) F. L. Lam, G. B. Brown, and J. C. Parham, *J. Org. Chem.*, **39**, 1391 (1974).
(8) L. Bauer, C. N. V. Nambury, and F. M. Hershenson, *J. Heterocyl. Chem.*, **3**, 224 (1966).
(9) T.-C. Lee, *J. Org. Chem.*, **38**, 703 (1973).
(10) G. Farao, *Mol. Photochem.*, **2**, 323 (1970).
(11) I. Ono and N. Hata, *Bull. Chem. Soc. Jpn.*, **46**, 3658 (1973).
(12) J. C. Parham, J. Fissekis, and G. B. Brown, *J. Org. Chem.*, **32**, 1151 (1967).
(13) J. C. Parham, T. G. Winn, and G. B. Brown, *J. Org. Chem.*, **36**, 2639 (1971).
(14) T.-C. Lee, F. L. Lam, and G. B. Brown, *J. Org. Chem.*, **40**, 1547 (1975).
(15) Y. Inoue and D. D. Perrin, *J. Chem. Soc.*, 2600 (1962).
(16) J. G. Calvert and J. N. Pitts, "Photochemistry", Wiley, New York, N.Y., 1966, p 783.

5,5,6,6,11,11,12,12-Octamethylcyclododeca-1,3,7,9-tetrayne

George Büchi* and Kin-Chun T. Luk

Department of Chemistry, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

Received July 7, 1977

3-Chloro-3-methyl-1-butyne (**1**) has been used in C, O, and N alkylations[1,2] as a convenient method for introducing the 1,1-dimethyl-2-propynyl group. It has also been employed as a precursor of dimethylvinylidene carbene (**2**).[3] Recently, when studying the alkylation of amines with **1**, a crystalline

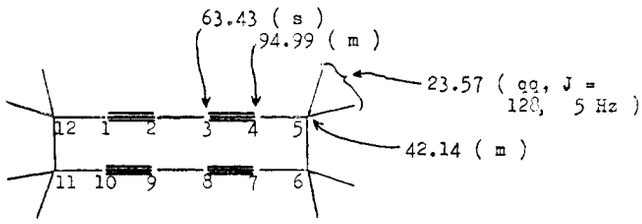


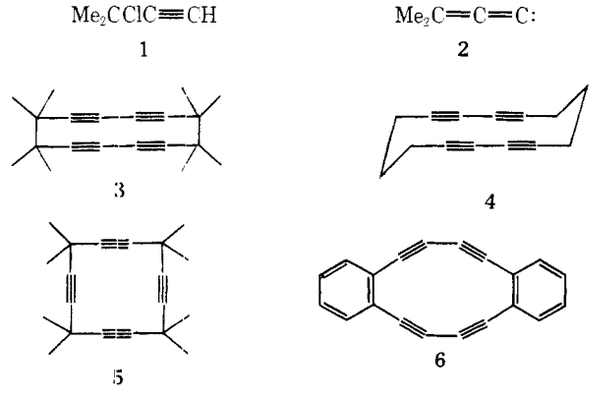
Figure 1. Carbon-13 chemical shifts of **3** in ppm downfield from tetramethylsilane, in $CDCl_3$ solution with the signal for $CDCl_3$ as internal standard.

side product **3** was obtained and its structure determination is reported herein.

Heating 3-chloro-3-methyl-1-butyne (**1**) with triethylamine and copper powder in benzene gave a crystalline compound after chromatography. High-resolution mass spectrometry and elemental analysis indicated a molecular composition of $C_{20}H_{24}$, while infrared spectroscopy showed **3** to be an acetylenic compound (2235 cm^{-1}). The ultraviolet spectrum of **3** in isooctane was very similar to that of cyclotetradeca-1,3,8,10-tetrayne (**4**),[4] and its proton nuclear magnetic resonance (^1H NMR) spectrum showed only one singlet attributed to methyl groups. These data suggested the structure 5,5,6,6,11,11,12,12-octamethylcyclododeca-1,3,7,9-tetrayne (**3**) for this new compound. A proton-decoupled ^{13}C NMR spectrum supported the above structure, and is consistent with spectra of similar 1,3-diacetylenes, especially that of **4**,[5] and excluded the possibility of the alternate structure 3,3,6,6,9,9,12,12-octamethylcyclododeca-1,4,7,10-tetrayne (**5**).[6] The observation of long-range coupling between the methyl protons and the external carbons of the diacetylenic units (i.e., C-1, -4, -7, and -10) and the absence of such coupling with the internal carbons (C-2, -3, -8, and -9) in the proton-coupled ^{13}C NMR spectrum (see Figure 1) supported the chemical-shift assignments and was consistent with those of similar 1,3-diacetylenes.[5,7]

Hydrogenation of **3** over platinum catalyst gave a compound with spectral properties consistent with 1,1,2,2,7,7,8,8-octamethylcyclododecane (see Experimental Section). In order to confirm the position of the methyl groups in structure **3** and its hydrogenation product, **3** was oxidized with neutral aqueous potassium permanganate. From the reaction mixture, a good yield of tetramethylsuccinic anhydride was obtained. The isolated tetramethylsuccinic anhydride was identified by its spectral data which were identical with those of authentic material prepared from diethyl tetramethylsuccinate.[8]

1,2:7,8-Dibenzocyclododeca-1,7-diene-3,5,9,11-tetrayne (**6**) has been synthesized,[9] and 1,3,7,9-cyclododecatetrayne was prepared in solution but was too unstable to be isolated.[10] Compound **3** represents the smallest, stable monocyclic compound (12-membered ring) containing two 1,3-diacetylenic units known to date.[11] The crude two-dimentional x-ray diffraction pattern of **6** revealed its structure to have two "bowed diacetylenic chains"[12] instead of the normal linear array of carbon atoms in diacetylenic units. In order to determine the actual molecular geometry of the macrocyclic tetrayne, single-crystal x-ray analysis of **3** is being undertaken and will be reported later. The formation of **3** from 3-chloro-3-methyl-1-butyne (**1**) can be rationalized in a number of ways but we favor a scheme in which two dimethylvinylidene carbenes (**2**) combine to give a cumulene with five double bonds. Dimerization of the latter might then produce the cyclic tetrayne **3**.



Experimental Section

Melting points determined on a Kofler hot-stage microscope or in a sealed tube using a Büchi SMP-20 melting point apparatus are corrected. Infrared (IR) spectra were recorded on a Perkin-Elmer 237B grating spectrophotometer and are reported in wavenumbers (cm^{-1}). The high-resolution mass spectrum (HRMS) was measured on a DuPont CEC-110B instrument; low-resolution mass spectra (MS) were determined on a Varian Mat 44 instrument. Nuclear magnetic resonance spectra were measured on a Varian T-60 (60 MHz) instrument for proton (^1H NMR), and on a Bruker HFX-90 (22.63 MHz) instrument for carbon-13 (^{13}C NMR), and are reported in parts per million (δ) downfield from tetramethylsilane; the abbreviations s, t, q, and m refer to singlet, triplet, quartet, and multiplet, respectively. Ultraviolet (UV) spectra were determined on a Cary-14 recording spectrophotometer and wavelengths are reported in nanometers (nm). Elemental analysis was performed by Robertson Laboratory, Florham Park, N.J.

5,5,6,6,11,11,12,12-Octamethylcyclododeca-1,3,7,9-tetrayne (3). To a solution of 3-chloro-3-methyl-1-butyne (**1**, 5 g, 48 mmol) in benzene (90 mL) in a 500 mL three-necked flask equipped with a condenser and a mechanical stirrer were added copper powder (5 g) and triethylamine (15 mL, 108 mmol). The stirred reaction mixture was heated at reflux for 16 h. After cooling to room temperature, the reaction mixture was filtered and the filtrate evaporated to near dryness under reduced pressure. This residue was filtered through a short silica gel column using dichloromethane as solvent. The eluate was concentrated and chromatographed on four 20 × 20 × 0.2 cm silica gel plates using 10% dichloromethane in hexane as solvent to give **3**, crystallized from chloroform–methanol mixture as white needles (106 mg, 3.3% yield): mp sublimed at 167 °C, decomposed violently above 180 °C in a sealed tube; IR ($CHCl_3$) 2980, 2945, 2875, 2235, 1460, 1440, 1390, 1375, 1365, 1300, 1180, 1145, 1125, and 1095 cm^{-1}; HRMS *m/e* found 264.18878, calcd for $C_{20}H_{24}$ 264.18780; MS *m/e* (rel intensity %) 264 (M^+, 24.5), 180 (100), 132 (76.5), 131 (26.5), 117 (47.5), 115 (38.0), 91 (44.5), 77 (33.0), 76 (22.5), 65 (23.5), 63 (22.0), 51 (32.5), 41 (40.0), 39 (57.0); ^1H NMR ($CDCl_3$) δ 1.20 (s); ^{13}C NMR ($CDCl_3$) δ 23.57 (qq, J = 128 and 5 Hz), 42.13 (m), 69.43 (s), and 94.99 (m); UV λ_{max} (isooctane) 239 (ϵ 730), 249 (805), and 264 (515) nm; UV λ_{max} (95% C_2H_5OH) 250 (ϵ 1100) and 265 (750) nm.

Anal. Calcd for $C_{20}H_{24}$: C, 90.85; H, 9.15. Found C, 90.39; H, 9.38.

1,1,2,2,7,7,8,8,-Octamethylcyclododecane. PtO_2 (82 mg) was hydrogenated in glacial acetic acid (10 mL) until hydrogen uptake ceased. A solution of **3** (58 mg, 0.22 mmol) in glacial acetic acid–ethyl acetate (v/v, 4:1, 10 mL) was injected into the hydrogenation flask. After coming to equilibrium, **3** was hydrogenated and the amount of hydrogen uptake monitored. Reaction stopped spontaneously after taking up 8 equiv of hydrogen (41.5 mL). The catalyst was filtered off and the filtrate diluted with ether (50 mL). The ether solution was washed with saturated aqueous sodium carbonate solution (2

× 50 mL) and dried (anhydrous sodium sulfate). After evaporating the solvent under reduced pressure, the residue was crystallized from a dichloromethane–methanol mixture to give white needles (59 mg, 96% yield): mp 63.0–63.5 °C; IR ($CHCl_3$) 2950, 1470, 1395, 1380, 1370, 1265 cm^{-1}; MS *m/e* (rel. intensity %) 280 (M^+, 0.27), 97 (28.0), 85 (23.5), 84 (30.5), 83 (62.5), 82 (30.0), 71 (29.0), 70 (29.0), 69 (100), 57 (67.5), 56 (80.5), 55 (80.0), 43 (60.0), 42 (21.5), 41 (95.0); ^1H NMR ($CDCl_3$) δ 0.83 (s, 3) and 1.37 (s, 2).

Oxidation of 3. A suspension of **3** (52.6 mg, 0.2 mmol) in aqueous potassium permanganate (828 mg, 5.2 mmol, in 50 mL) was heated at reflux for 20 h. After cooling to room temperature, the remaining permanganate was destroyed with sodium bisulfite. The reaction mixture was then acidified with sulfuric acid and extracted continuously with ether for 4 days. The ether extract was evaporated under reduced pressure to give an oil (24 mg), 95% by VPC, and was purified further by vacuum sublimation to give tetramethylsuccinic anhydride as a white gummy solid: mp sublimed without melting in a sealed tube; IR ($CHCl_3$) 2980, 1860, 1810, 1785, 1475, 1460, 1450, 1400, 1385, 1375, 1275, 1145, 970, 955, 920 cm^{-1}; MS *m/e* (rel. intensity %) 157 ($M^+ + 1$, 0.95), 156 (M^+, 0.13), 84 (100), 83 (21.0), 69 (100), 41 (71.5), 39 (41.5), 28 (32.0); ^1H NMR ($CDCl_3$) δ 1.24 (s).

Diethyl Tetramethylsuccinate. Diethyl tetramethylsuccinate was prepared from ethyl 2-methylpropanoate according the the method of T. J. Brocksom and co-workers.[13] The product so obtained was contaminated by an unknown compound [bp 77–78 °C (1 mm)]. Diethyl tetramethylsuccinate was separated from the contaminant by chromatography (silica gel, 1% ethyl acetate in hexane) followed by vacuum distillation: bp 79–80 °C (1 mm); IR ($CHCl_3$) 2990, 1725, 1470, 1445, 1400, 1385, 1370, 1270, 1170, 1125, 1025 cm^{-1}; MS *m/e* (rel. intensity %) 230 (M^+, 0.17), 185 (31.5), 157 (74.5), 116 (84.5), 115 (47.5), 111 (69.5), 88 (84.0), 87 (100.0), 85 (32.0), 84 (59.0), 83 (100.0), 73 (65.5), 70 (64.0), 69 (70.0), 59 (55.5), 57 (50.5), 55 (58.5), 43 (60.0), 42 (40.5), 41 (99.5), 39 (44.0), 29 (100.0), 28 (40.0), 27 (72.5); ^1H NMR ($CDCl_3$) δ 1.25 (s, 6), 1.25 (t, 3, J = 7 Hz), and 4.08 (q, 2, J = 7 Hz).

Tetramethylsuccinic Anhydride. Diethyl tetramethylsuccinate was hydrolyzed with aqueous ethanolic sodium hydroxide followed by acidification to give crude tetramethylsuccinic anhydride according to the procedure of D. J. Trecker and R. S. Foote.[8] The crude anhydride was purified by vacuum sublimation to give a gummy white solid with spectral properties identical to those mentioned above.

Acknowledgments. This work was supported by the National Cancer Institute (Contract 1CP 33217). The high-resolution mass spectrum was measured in the National Institute of Health supported facility at Massachusetts Institute of Technology (Grant FR 00317) under the direction of Professor K. Biemann. We are indebted to Dr. D. D. Traficante of the Department of Chemistry of M.I.T. for the ^{13}C NMR spectra, and Ms. R. Lüthi of the same department for the low-resolution mass spectra.

Registry No.—1, 1111-97-3; 3, 61414-48-0; 1,1,2,2,7,7,8,8-octamethylcyclododecane, 61414-47-9; tetramethyl succinic anhydride, 35046-68-5; diethyl tetramethyl succinate, 33367-54-3.

References and Notes

(1) R. V. Stevens and E. B. Reid, *Tetrahedron Lett.*, 4193 (1975).
(2) G. F. Hennion and J. F. Motier, *J. Org. Chem.*, **34**, 1319 (1969), and references cited therein.
(3) H. D. Hartzler, *J. Am. Chem. Soc.*, **83**, 4997 (1961); B. W. Bycroft, A. P. Johnson, and W. Landon, *J. Chem. Soc., D*, 463 (1969); R. W. Mills, R. D. H. Murray, and R. A. Raphael, *J. Chem. Soc., Perkin Trans. 1*, 133 (1973); M. Santelli and M. Bertrand, *Bull. Soc. Chim. Fr.*, 2380 (1973); T. Sasaki, S. Eguchi, and T. Ogawa, *J. Org. Chem.*, **39**, 1927 (1974), and *Heterocycles*, **3**, 193 (1975); S. Julia, D. Michelet, and G. Linstrumelle, *C. R. Hebd. Seances Acad. Sci., Ser. C.*, **278**, 1523 (1974).
(4) F. Sondheimer and Y. Gaoni, *J. Am. Chem. Soc.*, **81**, 6301 (1959).
(5) C. Charrier, D. E. Dorman, and J. D. Roberts, *J. Org. Chem.*, **38**, 2644 (1973).
(6) Compound **5** should give only three signals in the ^{13}C NMR spectrum but four were observed. See Experimental Section.
(7) R. Zeisberg and F. Bohlmann, *Chem. Ber.*, **107**, 3800 (1974).
(8) D. J. Trecker and R. S. Foote, *J. Org. Chem.*, **33**, 3527 (1968).
(9) O. M. Behr, G. Eglinton, A. R. Galbraith, and R. A. Raphael, *J. Chem. Soc.*, 3614 (1960); O. M. Behr, G. Eglinton, I. A. Lardy, and R. A. Raphael, *ibid.*, 1151 (1964).
(10) R. Wolovsky and F. Sondheimer, *J. Am. Chem. Soc.*, **87**, 5720 (1965), and references cited therein.
(11) Yields in this report were not optimized.
(12) W. K. Grant and J. C. Speakman, *Proc. Chem. Soc.*, 231 (1959).
(13) T. J. Brocksom, N. Petragnani, R. Rodrigues, and H. La Scala Teixeira, *Synthesis*, 396 (1975).

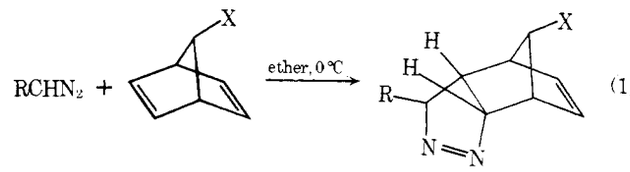
Addition of Diphenyldiazomethane to 7-Chloronorbornadiene. Implications for Orbital Control of 1,3-Dipolar Cycloadditions

James W. Wilt* and William N. Roberts

Department of Chemistry, Loyola University of Chicago, Chicago, Illinois 60626

Received August 5, 1977

Theoretical treatment of the 1,3-dipolar cycloaddition reaction has shown remarkable sophistication, leading to a rather detailed knowledge of this fascinating process.[1] One aspect of the cycloaddition that still seems somewhat unclear is its exo–endo selectivity in norbornadienes. Although generally recognized as a typical exo-addition process on a wide variety of norbornenes, the reaction proceeds via both exo and endo pathways in a number of cases involving norbornadienes.[2] It is therefore startling that the addition of either diazomethane or (better) diazoethane to the 7-halonorbornadienes has been reported to occur *solely* via an endo,anti pathway (eq 1).[3] This specificity has been attributed to a



(1)

R = H, 35%
R = CH_3, 80%

contribution by the σ^* orbital of the C–X bond to the LUMO of the diene.[3] Because 1,3-dipolar cycloadditions of the present type are believed to be controlled by the interaction between the HOMO of the diazo component and the LUMO of the diene,[1] this σ^* contribution is considered to be significant, and to favor an endo,anti approach by the diazoalkane. However, such an interpretation seemingly places minor importance on the diazoalkane.

Because diphenyldiazomethane adds to 7-*tert*-butoxynorbornadiene to give all four possible monoadducts,[2a] we were curious about its addition to a 7-halonorbornadiene. In fact, its reaction with 7-chloronorbornadiene showed no such specificity as in eq 1. Three monoadducts were formed (Scheme I): the endo,anti (58%); the endo,syn (16%); and the exo,anti (26%) isomers, **1**, **2**, and **3**, respectively. The yield of isolated material was 47%.

The structures of the three adducts seem secure. The endo adducts **1** and **2** were differentiated from the exo adduct **3** by the value of the NMR coupling constant $J_{1,2} \sim 3.5$ Hz in the former pair and ~1 Hz in the latter compound. Further structural evidence was gained from their remarkably clean photolysis to the corresponding tricyclic chlorides. Adduct **1** was photolyzed in acetone at 366 nm[4] to the very labile chlo-