elemental composition of this fragment ion.

The sign and magnitude of the optical rotations of OT-A, $[\alpha]^{25}_D$ + 67 ± 10° (EtOH, *c* 0.12), and DAT, $[\alpha]^{25}_D$ + 60.6 ° (EtOH, *c* 0.66), suggested that the two compounds have the same absolute configuration (C-29 uncertain).

Structures **3**, **4**, and **5** were deduced on the basis of low- (100 MHz) and high-frequency (360 MHz) proton magnetic resonance studies. The ^{1}H NMR spectra of the compounds assigned structures **3** and **4** differed from the ^{1}H NMR spectrum of OT-A primarily in the aromatic region. An AMX pattern at δ 6.82 (dd, 1 H, *J* = 8.0, 2.0 Hz), 7.05 (d, 1 H, *J* = 2.0 Hz), and 7.44 (d, 1 H, *J* = 8.0 Hz) was consistent with a 3,4-disubstituted phenol moiety in **3**. The ^{1}H NMR spectrum of **4** contained only two singlets (δ 7.22 and 7.64) in the aromatic region, in agreement with a 2,4,5-trisubstituted phenol system. The ^{1}H NMR spectrum of **5** showed a doublet at δ 1.11, indicating the presence of a methyl group on C-30, and it exhibited only two aromatic proton signals at δ 7.21 (s) and 7.63 (s). Again, the EI mass spectra of **3**, **4**, and **5** did not exhibit molecular ions, but characteristic M − H_2O peaks were observed and high-resolution measurements confirmed their elemental compositions.[6]

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References and Notes

(1) For a review see R. E. Moore, *BioScience*, **27**, 797, (1977).
(2) A. H. Banner in "Animal Toxins", F. E. Russell and P. R. Saunders, Eds., Pergamon Press, New York, N.Y., 1967, pp 157–165.
(3) J. S. Mynderse, R. E. Moore, M. Kashiwagi, and T. R. Norton, *Science*, **196**, 538 (1977).
(4) The toxicity and activity against P-388 lymphocytic leukemia in mice are comparable to those of DAT (M. Kashiwagi and T. R. Norton, unpublished results).
(5) Y. Kato and P. J. Scheuer, *Pure Appl. Chem.*, **41**, 1 (1975); Y. Kato and P. J. Scheuer, *Pure Appl. Chem.*, **48**, 29 (1976).
(6) Loss of water from the molecular ions of **3**, **4**, and **5** results in fragment ion clusters at *m/e* 638 and 640 (1:1) for **3** (high-resolution mass measurement: found, *m/e* 640.20810; calcd for $C_{31}H_{43}O_9{}^{81}Br$, 640.20706), *m/e* 716, 718, and 720 (1:2:1) for **4** (high-resolution mass measurement: found, *m/e* 718.11912; calcd for $C_{31}H_{42}O_9{}^{79}Br{}^{81}Br$, 718.11757), and *m/e* 730, 732, and 734 (1:2:1) for **5** (high-resolution mass measurement: found, *m/e* 732.13419; calcd for $C_{32}H_{44}O_9{}^{79}Br{}^{81}Br$, 732.13329).

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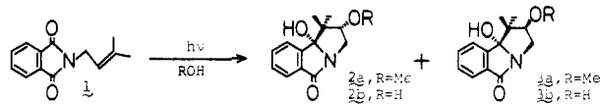
Photochemical Cyclization of *N*-2-Alkenyl- and *N*-3-Alkenylphthalimides

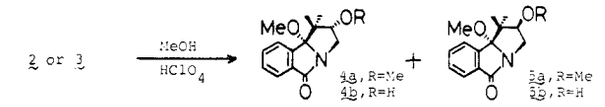
Summary: Photolysis of *N*-(3-methyl-2-butenyl)phthalimide (**1**) in methanol gave cyclic compounds **2a** and **3a** probably via successive processes; intramolecular electron transfer (**1** → **19**), polar addition of methanol (**19** → **20**), and cyclization of diradical (**20** → **2a** + **3a**).

Sir: It is well known that *N*-alkylated phthalimides undergo photochemical hydrogen abstraction reactions.[1] However, as far as we know, no examples of photochemical reactions of phthalimides with monoolefins have been published.[2] We now wish to report the first examples of photochemical reactions of phthalimides with monoolefins, in particular the intramolecular photochemical reactions of *N*-2-alkenyl- and *N*-3-alkenylphthalimides.

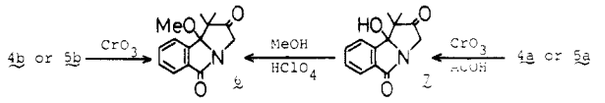
For example, a solution of *N*-(3-methyl-2-butenyl)-phthalimide (**1**) (5 mM) in methanol was irradiated under N_2



with a 300-W high-pressure Hg-arc lamp (Eikosha PIH-300) through quartz for about 5 h.[3] At this stage, the starting material had almost disappeared. After workup, two products were obtained. The structure and stereochemistry of the isomeric products ($C_{14}H_{17}NO_3$, mass *m/e* 247, elemental analyses) **2a** (41%, mp 98–99 °C) and **3a** (41%, mp 200–201 °C) were assigned as the following. **2a:** IR (KBr) 3400 (OH), 1685 cm^{-1} (amide); ^{1}H NMR ($CDCl_3$) δ 0.42 (s, 3 H, Me), 1.42 (s, 3 H, Me), 3.48 (s, 3 H, OMe), 3.5–3.9 (m, 3 H), 4.51 (s, 1 H, OH), 7.3–7.9 (m, 4 H). **3a:** IR (KBr) 3250 (OH), 1680 cm^{-1} (amide); ^{1}H NMR ($CDCl_3$) δ 0.32 (s, 3 H, Me), 1.40 (s, 3 H, Me), 3.07 (s, 1 H, OH), 3.27 and 3.62 (two dd, 2 H, NCH_2), 3.43 (s, 3 H, OMe), 4.37 (t, 1 H, methine), 7.3–7.8 (m, 4 H). The products **2a** and **3a** were resistant to acetylation by acetic anhydride–pyridine and to chromic acid oxidation, but they were converted to an equilibrium mixture of methyl ethers, **4a** (mp 89–90 °C)/**5a** (mp 98–99 °C) = 3:1, probably via a

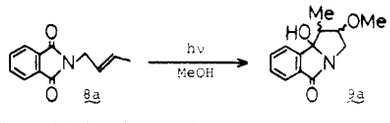


common stable tertiary carbonium ion, on treatment with a trace amount of acid ($HClO_4$) in methanol. Diols **2b** (mp 172–174 °C) and **3b** (mp 178–181 °C), which were obtained by photolysis of **1** in water–acetonitrile (v/v 1:8) in a yield of 70% (**2b**/**3b** = 1:1), were converted to an equilibrium mixture of monomethyl ethers **4b** (oil)/**5b** (oil) = 3:1 by a similar procedure. The secondary alcohol **4b** was easily oxidized to ketone **6** (50%, mp 108–110 °C) by Jones oxidation. The ketone **6** was

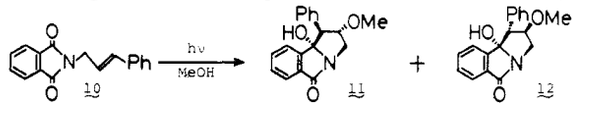


also obtained by the reverse manipulation; i.e., initial oxidation of **4a** accompanied by hydrolysis to **7** (72%, mp 200–202 °C) followed by methylation to give **6**. ^{1}H NMR spectra of **2a** and **3a** showed the presence of two kinds of *C*-methyl groups. The anisotropic shielding effect of the phenyl ring is probably responsible for the higher chemical shift of one of the two methyl groups. Similarly in **2–7** one of the two methyl groups had its ^{1}H NMR signals at δ 0.28–0.50. The stereochemistry of **2–5** was assigned on the basis of their ^{1}H NMR spectra. Thus, for the isomers **2** or **4**, the higher field shift of the methine protons compared to those of the corresponding isomers **3** or **5** (for example, **3a** − **2a** = 0.5, **3b** − **2b** = 0.58 ppm HCOMe) is explicable in terms of the same anisotropic effect seen for the methyl groups. Further support for these structures will be shown in connection with other photoproducts (vide infra). Photolysis (10 h) of **1** in acetonitrile resulted in recovery of the starting material.

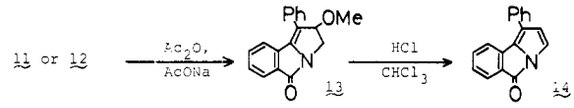
Irradiation of *N*-(2-butenyl)phthalimide (**8a**) in methanol gave the corresponding products **9a** (mixture, 75%), but *N*-allylphthalimide (**8b**) afforded no corresponding products on photolysis in methanol.



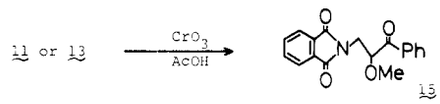
Photolysis of *N*-(3-phenyl-2-propenyl)phthalimide (**10**) in methanol gave **11** (68%, mp 162–164 °C) and **12** (17%, mp



189–191 °C). On refluxing **11** and **12** in acetic anhydride and sodium acetate for 0.5 h, respectively, we readily obtained the same dehydrated product **13** (pale yellow crystals, mp 164–166 °C). The product **13** was further converted to **14** (orange

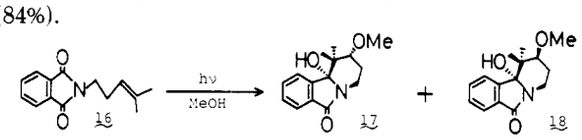


crystals, mp 113–115 °C) by treating with hydrochloric acid in chloroform. The main photoproduct **11** was quantitatively oxidized to **15** (mp 135–136 °C) by chromic acid oxidation in acetic acid. In a similar manner, **13** was oxidized to **15** (50%).



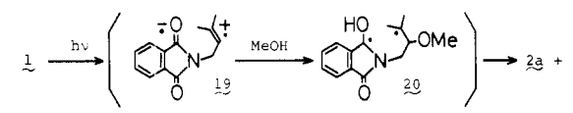
The structure of **11** was confirmed by X-ray diffraction. The stereochemistry of **12** is assigned on the basis of its ^{1}H NMR spectra compared with that of **11**: partial ^{1}H NMR (δ) of **11**, 4.1–4.4 (m, 2 H, two methine), 3.78 (m, 2 H, NC**H**$_2$); **12**, 4.92 (m, 1 H, **H**COMe), 3.74 and 3.50 (two dd, 2 H, NC**H**$_2$), 2.76 (d, 1 H, **H**CPh). On irradiation of **10** in methanol, the presence of a triplet quencher (penta-1,3-diene, 1 mol/L) did not significantly affect the rate of formation of the photoproducts, analogous to the case of photolysis of *N*-(dibenzylaminomethyl)phthalimide.[1e]

Irradiation of *N*-(4-methyl-3-pentenyl)phthalimide (**16**) in methanol gave the corresponding isomers **17**/**18** = 1:1 (84%).



These intramolecular photocyclizations of phthalimides may be reasonably explained by a mechanism involving initial one-electron transfer.[4] Thus, for example, in the photocyclization of **1**, the primary photoprocess may be one-electron transfer from the double bond (**1** → **19** in Scheme I) followed by polar addition of methanol to give a diradical (**19** → **20**)[5] which cyclizes to produce **2a** and **3a**.[6]

Scheme I



The reaction pattern of the photocyclization of *N*-alkenylphthalimide described above seems to be novel in the widely studied photochemistry of carbonyl compounds with olefins. The scope, limitation, and detailed mechanism of this reaction are under investigation.

Acknowledgment. We are indebted to Professor Masao Kakudo and Dr. Nobuo Tanaka of Osaka University (the Institute for Protein Research) for X-ray diffraction analysis.

References and Notes

(1) (a) Y. Kanaoka, *Yuki Gosei Kagaku Kyokai Shi*, **33**, 949 (1975), and papers cited therein; (b) Y. Sato, H. Nakai, T. Mizoguchi, and Y. Kanaoka, *Tetrahedron Lett.*, 1889 (1976); (c) Y. Sato, H. Nakai, T. Mizoguchi, Y. Hatanaka, and Y. Kanaoka, *J. Am. Chem. Soc.*, **98**, 2349 (1976); (d) H. J. Roth and D. Schwarz, *Arch. Pharm.*, **308**, 631 (1975); (e) J. D. Coyle and G. L. Newport, *Tetrahedron Lett.*, 899 (1977).

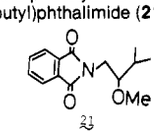
(2) Light-induced reaction of *N*-methylphthalimide with cycloalkenes has been reported, but the report described only an α-hydrogen abstraction from cycloalkenes.[2a] Photochemical oxetane formation of *N*-2-alkenyl alicyclic imides[2b] and photoaddition of dienes to *N*-methylphthalimide[2c] have been reported. (a) Y. Kanaoka and Y. Hatanaka, *Chem. Pharm. Bull.*, **22**, 2205 (1974); (b) K. Maruyama and Y. Kubo, *J. Org. Chem.*, **42**, 3215 (1977); (c) P. H. Mazzocchi, M. J. Bowen, and N. K. Narain, *J. Am. Chem. Soc.*, **99**, 7063 (1977).

(3) All new compounds gave satisfactory analytical results as well as reasonable spectral properties (IR, NMR, UV, and mass spectra).

(4) It is reported that in the photochemical reaction of aromatic esters with olefins in polar solvents, the exciplexes, once formed, dissociate into the radical ions.[4a-c] Furthermore, in the photohydrogen abstraction reaction of phthalimides, electron transfer (or CT) mechanisms are often regarded as playing an important role.[1] (a) R. A. Neunteufel and D. R. Arnold, *J. Am. Chem. Soc.*, **95**, 4080 (1973); (b) Y. Shigemitsu and D. R. Arnold, *J. Chem. Soc., Chem. Commun.*, 407 (1975); (c) A. J. Maroulis, Y. Shigemitsu, and D. R. Arnold, *J. Am. Chem. Soc.*, **100**, 535 (1978).

(5) Photosensitized anti-Markownikoff addition of alcohols (involving electron transfer) to olefins has been reported[4a-c] and the protonation of a carbonyl group from a CT complex by methanol has been postulated.[5a] The diradical is also a presumed intermediate in the intramolecular δ-hydrogen abstraction reaction of *N*-alkylphthalimides.[1] (a) P. J. Wagner and D. A. Ersfeld, *J. Am. Chem. Soc.*, **98**, 4515 (1976).

(6) Another mechanism for the photolysis of **1** is the possible intermediacy of *N*-(2-methoxy-3-methylbutyl)phthalimide (**21**) (via sensitized anti-Markownikoff addition of methanol to the double bond) followed by δ-hydrogen abstraction to **2a** and **3a**. However, in our hands **21** could not be isolated under various conditions. Furthermore, a photoreaction of **21** is anticipated to occur with preferential γ-hydrogen rather than δ-hydrogen abstraction as is observed in the photolysis of *N*-(3-methylbutyl)phthalimide.[1a]



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Diels–Alder Reaction of 1,4-Quinone Monobenzenesulfonimides

Summary: The Diels–Alder cycloaddition of a series of 1,4-quinone monobenzenesulfonimides with various 1,3-butadienes was investigated. The objective was to determine the influence of the benzenesulfonimide group on the regiochemistry of the cycloaddition as well as the relative dienophile double bond reactivity. The salient results are: (1) the regiochemistry of the cycloadditions is exclusively controlled by the benzenesulfonimide group; (2) the double bond in the quinone imine which is syn to the benzenesulfonimide is the more activated dienophilic position.

Sir: Synthetic strategy for the construction of a large number of naturally occurring quinones, including the biologically significant anthracycline antineoplastic antibiotics, utilizes a Diels–Alder cycloaddition of a quinone to a diene. However, this methodology often suffers both regiochemical and reactivity problems. That is, in the cycloaddition of a substituted benzoquinone with a substituted diene, the regiochemical problem concerns the orientation of the substituents in the final product, and the reactivity problem concerns the relative reactivity of the enone double bonds in the quinone dienophile.[1] These conflicts are dramatically illustrated in the elegantly simple synthesis of (±)-daunomycinone reported by Kende, Tsay, and Mills.[2] Here it was observed that the key intermediate, 5-methoxy-1,4,9,10-anthradiquinone (**1**), reacts with most electron-rich dienes at the internal 4a,9a double

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