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Photoactivation of Amino-Substituted 1,4-Benzoquinones for Release of Carboxylate and Phenolate Leaving Groups Using Visible Light

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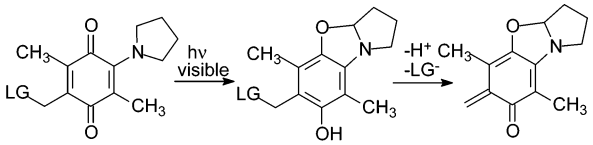
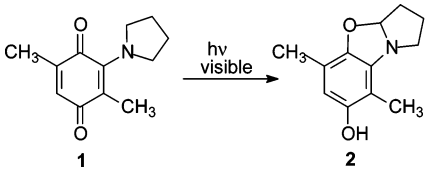


$LG^- = PhCH_2CO_2^-$, $PhCO_2^-$, $4\text{-}CNC_6H_4CO_2^-$, $C_6H_5O^-$, $4\text{-}CF_3C_6H_4O^-$, $4\text{-}CNC_6H_4O^-$

Upon exposure to visible light, 2-pyrrolidino-substituted 3,6-dimethyl-1,4-benzoquinones photocyclize to give benzoxazolines with quantum yields of 0.07−0.10 in CH_2Cl_2, 0.02−0.04 in CH_3CN, and <0.01 in 30% aq CH_3CN. With carboxylate or phenolate leaving groups incorporated via coupling to a 5-hydroxymethyl group of the quinones, the photocyclizations give benzoxazolines that eliminate the leaving groups in a dark reaction. Lifetimes for elimination of $4\text{-}YC_6H_4OH$ in 30% phosphate buffer in CD_3CN (pD 7) at 17 °C are 13.1, 0.54, and 0.13 h for Y = H, CF_3, and CN, respectively, and the linear equation log k (h^{-1}) = 0.998(−pK_a) + 8.80 gives a best fit to the data. Carboxylate leaving groups are rapidly eliminated upon photolysis of the quinones in aq CH_3CN to produce an *o*-quinone methide intermediate that is trapped by 4 + 2 cycloaddition with unreacted starting material or with added 3-(dimethylamino)-5,5-dimethyl-2-cyclohexen-1-one. The ortho-quinone methide is observed at 339 and 455 nm by conventional absorption spectroscopy and gives a pseudo-first-order fit of the decay kinetics with $\tau_{1/2}$ = 34.9 min in 30% phosphate buffer in CH_3CN at 20 °C.

Introduction

Dialkylamino-substituted 1,4-benzoquinones have been shown to undergo rearrangement to isomeric benzoxazolines when exposed to sunlight.[1] The photorearrangement has been exemplified by 2-pyrrolidino-1,4-benzoquinone **1**, which gives benzoxazoline **2** as a photoproduct (eq 1).[2] In a previous commu-



1 **2** (1)

nication,[3] we considered the possibility that the structurally related 2-pyrrolidino-1,4-benzoquinone **3** would photorearrange to an unstable benzoxazoline photoproduct **4** that would expel leaving groups (LG^-) such as carboxylate groups or phenolate groups in a subsequent dark elimination reaction. The 2-pyrrolidino-1,4-benzoquinone **3** could then serve as a photocleavable group that would unmask functionality upon activation through the use of visible light. The use of visible light would be important in differentiating among multiple photolabile groups in the selective deprotection of polyfunctional molecules.[4] Achieving such wavelength-selective photochemistry can be considered one of the major challenges in photodeprotection chemistry. Among the potential difficulties is the fact that few photocleavable groups are available that are sensitive to light in the visible wavelength region. With few exceptions,[5,6]

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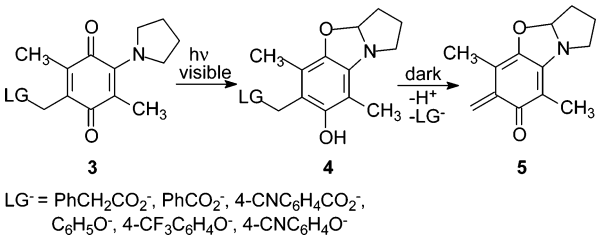
SCHEME 1



the wavelengths that can be used for the photoremoval of protecting groups lies below about 400 nm.

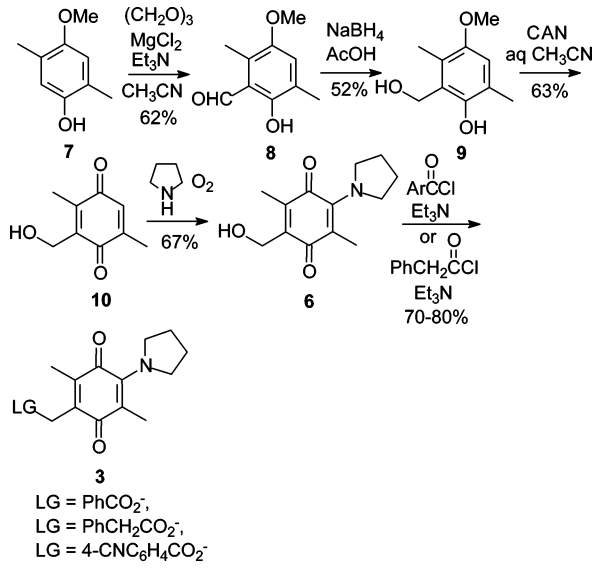
In this paper, we report in full on the photochemistry of 2-pyrrolidino-1,4-benzoquinones **3** which bear various carboxylate and para-substituted phenolate leaving groups, LG^- (Scheme 1). Under aqueous conditions, the carboxylate leaving groups are rapidly expelled upon photocyclization to the benzoxazolines **4**. The loss of the carboxylate leaving groups produces a trappable *o*-quinone methide intermediate, which can also be observed by absorption spectroscopy. With the phenolate leaving group the photocyclized product, **4**, is observable by NMR spectroscopy during photolyses under aqueous conditions, and para-substituted phenolate derivatives of **4** can be isolated after photolyses in nonaqueous solvents. Kinetics investigations of the release of para-substituted phenolate groups give a linear Bronsted-type correlation of release rates and leaving group basicity from which the release times of the labile carboxylate leaving groups from **4** can be estimated to be on the millisecond time scale.

Results

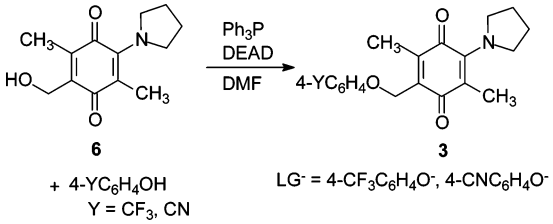
Synthesis. 5-Hydroxymethyl-1,4-benzoquinone **6** was a key intermediate in the synthesis of 2-pyrrolidino-1,4-benzoquinones **3** bearing carboxylate and para-substituted phenolate leaving groups. The synthesis of **6** involved ortho formylation[7] of 2,5-dimethyl-4-methoxyphenol **7**[8] to give the 2-hydroxybenzaldehyde **8** (Scheme 2), followed by sodium borohydride reduction[9] of the aldehyde group, which furnished benzylic alcohol **9**. The phenolic ether **9** was oxidized[10] to the quinone **10**, which was converted to **6** by reaction with pyrrolidine in the presence of air to oxidize a hydroquinone intermediate that would be expected to be formed in this reaction. The carboxylate leaving groups ($LG^- = PhCO_2^-$, $PhCH_2CO_2^-$, $4\text{-}CNC_6H_4CO_2^-$) were introduced by acylation of **6** using the corresponding acid chlorides (Scheme 2). The 2-pyrrolidino-1,4-benzoquinones **3** were obtained as red-purple crystalline compounds that showed strong absorption in the 450−650 nm wavelength region in aqueous solution. Compounds **3** were stable in aqueous CD_3CN in the dark and showed no signs of reaction for periods of at least a week. Neat **6** was stable to storage for months at −22 °C.

A Mitsunobu coupling procedure[11] was used to introduce phenolic groups at the hydroxymethyl group of quinone **6** to

SCHEME 2

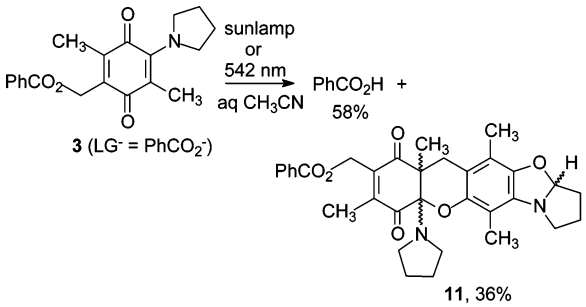


obtain **3** ($LG^- = 4\text{-}YC_6H_4O^-$, Y = CF_3, CN) in 33% and 37% yields, respectively (eq 2). This procedure circumvented the low yields obtained from our previously reported route, which was used to synthesize **3** ($LG^- = PhO^-$).[3]



(2)

Photolyses of Carboxylate Derivatives of 3. The photochemistry of 2-pyrrolidino-1,4-benzoquinones **3** was initially investigated with the benzoate derivative ($LG^- = PhCO_2^-$). Photolysis of 0.02 M solutions in 30% D_2O in 70% CD_3CN with a 120 W sunlamp produced benzoic acid in 58% yield at 100% conversion, according to ^1H NMR spectroscopy. An additional photoproduct, present in 36% yield, was chromatographically isolated and identified by ^1H and ^{13}C NMR spectroscopy and elemental analysis as **11** (eq 3). Compound



(3)

11 appeared to be a 1:1 mixture of diastereomers. Its structure suggested that it could have been produced via cycloaddition of the *o*-quinone methide intermediate **5** with starting material **3** ($LG^- = PhCO_2^-$). Consumption of **3** ($LG^- = PhCO_2^-$) by such a cycloaddition during photolysis would account for the less than 100% yield of released benzoic acid observed. Similar

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(9) Witiak, D. T.; Loper, J. T.; Almerico, S. A. M.; Verhoef, V. L.; Filppi, J. A. *J. Med. Chem.* **1989**, *32*, 1636−1642.

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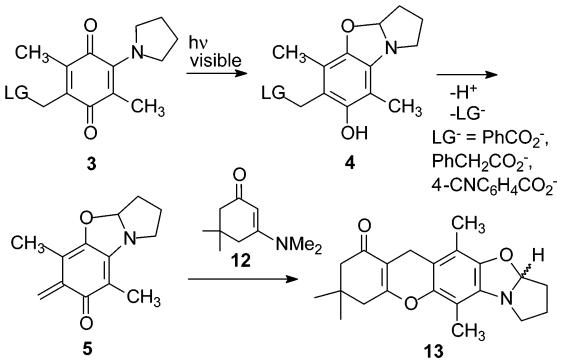
SCHEME 3



results were obtained upon photolysis of **3** ($LG^- = PhCO_2^-$) with 542 nm light that had been passed through a monochromator.

To trap the *o*-quinone methide **5** intermediate, photolyses were conducted with various alkenes. Irradiation of 10^{-2} M **3** ($LG^- = PhCO_2^-$, $PhCH_2CO_2^-$, $4\text{-}CNC_6H_4CO_2^-$) with 0.1 M 3-(dimethylamino)cyclohexen-1-one **12** in 30% aqueous CH_3CN produced the cycloadduct **13** (Scheme 3). The cycloadduct was isolated chromatographically and identified by ^1H and ^{13}C NMR analyses and Elemental Analysis. The structure was confirmed by X-ray crystallography. The yields of the carboxylic acids produced in these photolyses were 89−92%, and the cycloadduct **13** was produced in 79−87% yields at 100% conversions of the reactants. Other alkene trapping reagents for *o*-quinone methides,[12] such as dihydropyran, ethyl vinyl ether, methyl trimethylsilyl dimethylketene acetal, and diethyl fumarate, were insufficiently reactive in trapping the *o*-quinone methide, which is deactivated by multiple electron-releasing substituents, and the photolyses of **3** gave essentially the same results as those conducted without the added trapping reagent.

The quantum yields for disappearance of 10^{-3} M 2-pyrrolidino-1,4-benzoquinones **3** ($LG^- = PhCH_2CO_2^-$, $PhCO_2^-$, $4\text{-}CNC_6H_4CO_2^-$) in the presence of 0.1 M **12** were determined at 458 nm in air-saturated 30% aq CH_3CN. These quantum yields for disappearance should approximately equal the quantum yields for formation of the carboxylic acids because the acids are produced in ca. 90% yields when **12** is present to prevent trapping of *o*-quinone methide **5** by the reactant (vide supra). The values for Φ_{dis} were 0.005−0.006 for the three carboxylate derivatives, whereas without added **12**, higher values ($\Phi_{dis} = 0.007-0.008$) were found. In the case of **3** ($LG^- = PhCO_2^-$), the quantum yield for the appearance of the benzoic acid, determined by HPLC analyses, was the same as Φ_{dis}. In addition, for **3** ($LG^- = PhCH_2CO_2^-$) the quantum yield was unchanged upon purging the sample with argon.

Spectroscopic Studies. Spectroscopic evidence for the formation of *o*-quinone methide intermediate **5** during photolyses of 5×10^{-4} M **3** ($LG^- = PhCO_2^-$) in 30% aqueous CH_3CN was obtained by absorption spectroscopy. The photolyses were conducted with a sunlamp, maintaining the sample at 2 °C, and the experiment was repeated using 542 nm light passed through a monochromator. In both experiments new absorption bands were observed at 339 and 455 nm, along with residual absorption of unreacted quinone **3** at 542 nm, after 30 min of photolysis (Figure 1A). The new absorption bands were assigned to *o*-quinone methide **5** and were similar to those of other *o*-quinone methide intermediates.[13] When the photolysates were warmed to 20 °C, the 339 and 455 nm bands slowly disappeared, and the rate of disappearance was found to substantially increase upon addition of 8×10^{-3} M dimethylaminocyclohexenone **12**, consistent with the above trapping experiments. In 30% phosphate buffer in CH_3CN at pH 6.95 as the medium, the observed decay of the 339 nm absorption band was fit to pseudo-first-order kinetics (Figure 1B), which gave an estimate for the half-life of **5** of 34.9 ± 0.4 min at 20 °C ($R^2 = 0.9991$, 95% confidence interval). This value for the half-life supersedes our previously reported[3] half-life for **5**, which was miscalculated. Pseudo-first-order decay kinetics would be consistent with disappearance of the *o*-quinone methide **5** by a hydration reaction.[12,14]

Nanosecond laser flash photolysis experiments were performed in attempts to determine the rate constant for formation of *o*-quinone methide from **3** ($LG^- = PhCO_2^-$), since this would reflect the leaving group release rate. However, we were unable to detect the 339 nm absorption of **5** upon 265 nm nanosecond laser flash photolysis of **3** ($LG^- = PhCO_2^-$). Evidently **5** was formed too slowly for the time resolution of our instrument. In addition, the quantum yield for **5** could be too low to give a detectable signal. We also attempted to monitor the kinetics of the proton release step using the previously reported time-resolved pH jump method.[15c,d] Although photolysis of 2.74×10^{-4} M **3** ($LG^- = PhCO_2^-$) in 30% aq CH_3CN to complete conversion caused a decrease in the 620 nm absorption of the bromocresol green, no signal for bleaching of this band could be detected in the 355 nm laser flash photolysis experiment.

Photocyclization to Benzoxazolines 4. Phenolate derivatives of **3** ($LG^- = 4\text{-}YC_6H_4O^-$, Y = H, CF_3, CN) underwent photocyclization under nonaqueous conditions, and the corresponding benzoxazoline photoproducts **4** ($LG^- = 4\text{-}YC_6H_4O^-$, Y = H, CF_3, CN) were sufficiently stable to be isolated. However, under aqueous conditions at neutral or basic pH these benzoxazolines were unstable with respect to elimination of the para-substituted phenolate groups (vide infra).

Photolysis of 10^{-2} M **3** ($LG^- = PhO^-$) in CD_2Cl_2 or CD_3CN with a sunlamp gave the photocyclization product, benzoxazoline **4** ($LG^- = PhO^-$), as the sole photoproduct in 100% yield after complete conversion of the reactant (Scheme 1) according to ^1H NMR analyses with DMSO as an NMR standard. In preparative-scale photolyses, no further purification of **4** ($LG^- = PhO^-$) was necessary after evaporation of the solvent upon completion of the photolyses. Similarly, photolyses of **3** ($LG^- = 4\text{-}YC_6H_4O^-$, Y = CF_3, CN) gave 100% yields of NMR pure **4** ($LG^- = 4\text{-}YC_6H_4O^-$, Y = CF_3, CN) at 100% conversions of the reactants.

The quantum yields for photocyclization of **3** ($LG^- = PhO^-$) to give benzoxazoline **4** ($LG^- = PhO^-$), irradiating at 458 nm, were determined in the air-saturated solvents CH_2Cl_2 and CH_3-

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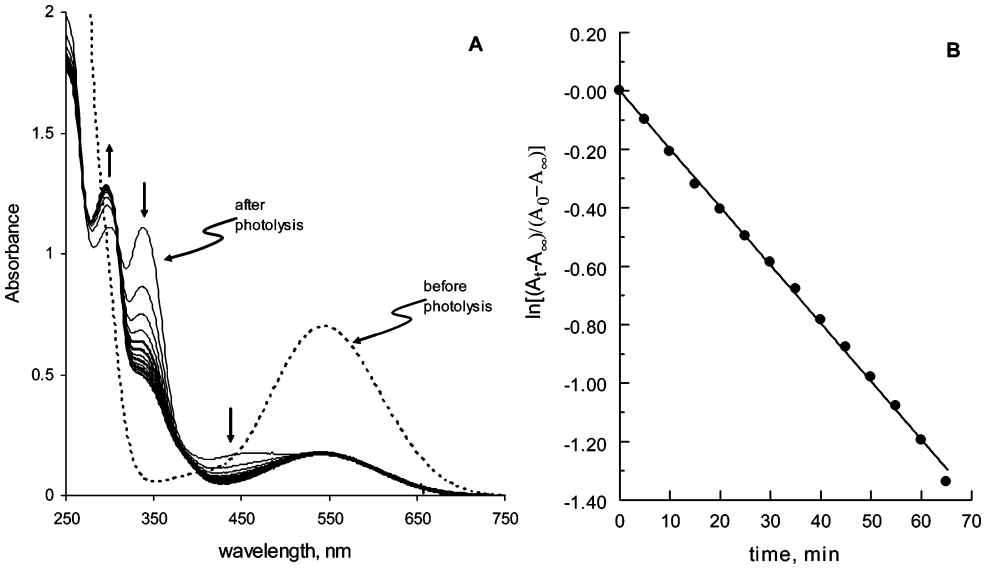


FIGURE 1. (A) Absorption spectrum of **3** ($LG^- = C_6H_5CO_2^-$) before photolysis in 30% aq CH_3CN (- - -) at 2 °C and after photolysis (—), upon warming to 20 °C; scans after photolysis show changes in absorbance at 10 min time intervals. (B) Pseudo-first-order fit of the decay of the absorbance at 339 nm in 30% phosphate buffer in CH_3CN at pH 6.95 at 20 °C.

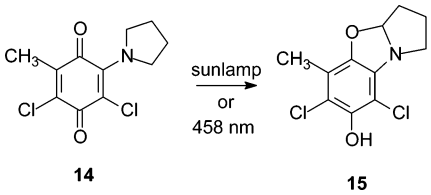
TABLE 1. Quantum Yields for Photocyclization of Amino-1,4-benzoquinones 3, 14, and 1 To Give Benzoxazolines, Irradiating at 458 nm

	Φ, solvent		
reactant	30% aq CH_3CN[a]	CH_3CN[b]	CH_2Cl_2[b]
3 ($LG^- = OPh$)	nd[c]	0.040	0.10
1	0.007	0.031	0.090
14	0.003	0.024	0.074

[a] Quantum yields of disappearance of the quinones, determined by absorption spectroscopy. [b] Quantum yields of appearance of benzoxazoline photoproduct determined by ^1H NMR spectroscopy. [c] Not determined.

CN. The quantum yields decreased with increasing polarity of the solvent (Table 1).

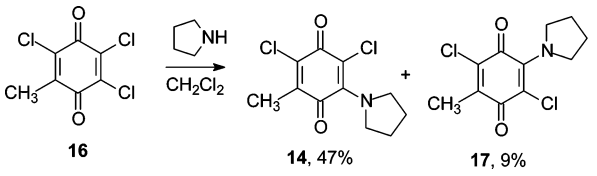
To determine whether the solvent effects on quantum yields for cyclization of **3** ($LG^- = PhO^-$) are general for 2-amino-1,4-benzoquinones, we compared the solvent effects on quantum efficiencies for 2-pyrrolidino-1,4-benzoquinone **1** (eq 1), which was reinvestigated,[2] and the photocyclization of dichloro-1,4-benzoquinone **14** (eq 4). In addition to determining the quantum



(4)

yields (Table 1), preparative photolysis of 0.037 M 2-pyrrolidino-1,4-benzoquinone **1** in CH_2Cl_2 was conducted, and benzoxazoline **2** was obtained in 73% isolated yield after silica gel chromatography and crystallization. Preparative photolysis of **14** gave benzoxazoline **15** in 100% yield at 100% conversion of reactant, according to ^1H NMR analyses of the photolysate with DMSO as a standard.

It should be noted that the synthesis of 3,5-dichloro-2-pyrrolidino-1,4-benzoquinone **14** involved the addition of pyrrolidine to trichloroquinone **16**[16] (eq 5). Dichloroquinone **14** was obtained as the major regioisomer, as established by X-ray crystallography. The minor regioisomer was thought to be **17**, which was not photolyzed due to its low yield.



(5)

Elimination Reactions of Benzoxazolines 4. Under aqueous conditions, the benzoxazolines **4** ($LG^- = 4\text{-}YC_6H_4O^-$, Y = H, CF_3, CN) underwent elimination of the para-substituted phenolate leaving groups at neutral or basic pH. For example, the loss of phenol from **4** ($LG^- = PhO^-$) was observed by ^1H NMR spectroscopy at pD 7 in 30% phosphate buffer in CD_3CN. At 17 °C first-order kinetics were observed with a lifetime of 13.1 h ($\tau_{1/2}$ = 9.1 h), whereas at the more acidic pD of 5.6, the benzoxazoline showed no sign of undergoing elimination phenol (vide infra). Under nonaqueous conditions in CD_2Cl_2 or CD_3CN, the eliminations of phenol could be effected by adding Et_3N to the solutions of **4** ($LG^- = PhO^-$).

We investigated whether the elimination of phenol would be observed during a photolysis of **3** ($LG^- = PhO^-$) that produced **4** ($LG^- = PhO^-$) under the same buffered conditions as above (Figure 2). Accordingly, benzoxazoline **4** ($LG^- = PhO^-$) was produced in 73% yield along with 2.7% of **11** ($LG^- = PhO^-$) and 8% of phenol at 86% conversion at pD 7, whereas at pD 5.6 the benzoxazoline **4** ($LG^- = PhO^-$) was produced in 100% yield at complete conversion of the reactant. From the data at pD 7 (Figure 2), it was evident that the phenol produced by photolysis could be accounted for by "dark" elimination of **4** ($LG^- = PhO^-$). While monitoring this photolysis by ^1H NMR spectroscopy, broad peaks were also observed which suggested the accompanying formation of high molecular weight material which could not be readily identified.

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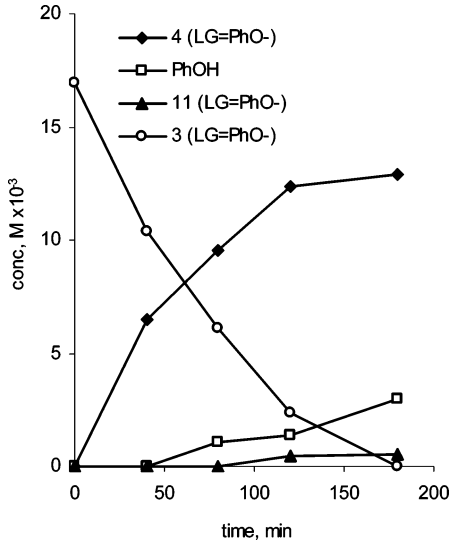

FIGURE 2. Concentration versus time profile for photolysis of **3** ($LG^- = PhO^-$) in 30% phosphate buffer in CD_3CN at pD 7.

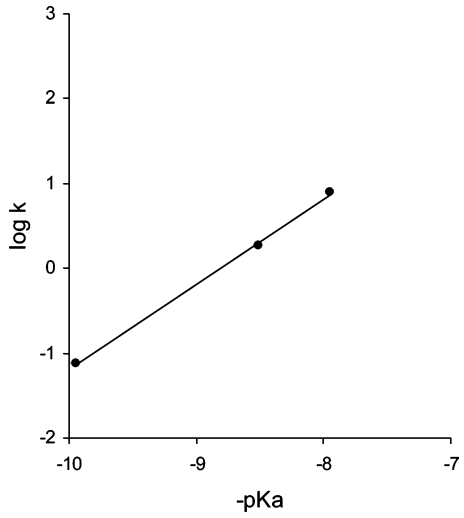

FIGURE 3. Plot of log k vs $-pK_a$ for the release of 4-YC_6H_4OH (Y = H, CF_3, CN) from **4** in 30% phosphate buffer at 17 °C.

The kinetics for the release of the para-substituted phenolic groups from **4** dissolved in 30% phosphate buffer in CD_3CN (pD 7) at 17 °C were then monitored by ^1H NMR spectroscopy to obtain the rate constants for the release of 4-YC_6H_4OH (Y = CF_3, CN). The lifetimes ($1/k_{release}$) for the release of 4-YC_6H_4-OH (Y = CF_3, CN) were found to be 0.54 and 0.13 h, respectively. With the kinetic data for phenol included (vide supra), the linear equation log k (h^{-1}) = $0.998(-pK_a) + 8.80$ gave a best fit to the data (Figure 3).

Discussion

2-Pyrrolidino-1,4-benzoquinones **3** bearing phenolate leaving groups photocyclize to benzoxazolines **4** ($LG^- = 4\text{-}YC_6H_4O^-$, Y = H, CF_3, CN) upon exposure to light in the 460−650 nm wavelength region. Chemical yields of **4** ($LG^- = 4\text{-}YC_6H_4O^-$, Y = H, CF_3, CN) are 100% at complete conversion of the photochemical reactants **3** ($LG^- = 4\text{-}YC_6H_4O^-$, Y = H, CF_3, CN) when the photolyses are conducted in CH_2Cl_2 or CH_3CN as the solvents. Although the quantum yield for the photocyclization of **3** ($LG^- = PhO^-$) to benzoxazoline is 0.10 in CH_2Cl_2, lower efficiency is observed for photolysis in the more polar solvent, CH_3CN. Pronounced decreases in efficiencies with polar solvents are also observed for the other 2-pyrrolidino-1,4-benzoquinones **1** and **14** (Table 1). The decreased quantum efficiencies in going to polar solvents imply the involvement of an intramolecular charge transfer (ICT) excited state[17−19] in the photochemical formation of the benzoxazolines. As shown in Scheme 4, the initial ICT excited state would be subject to rapid back electron transfer (bet) to regenerate the ground state reactant upon stabilization of this excited state in polar solvents. The bet could be competing with the hydrogen transfer step that would be required to ultimately form the cyclized product **4**.

It is possible that the immediate precursor in the photocyclization to benzoxazoline **4** is zwitterionic in character in the ground state, as with structure **19** in Scheme 4. Evidence from studies of the photochemistry of α-keto amides bearing leaving groups at the position α to the keto group[15] shows that intermediates analogous to **19** can cyclize as well as expel phenolate and carboxylate leaving groups. However, in the photochemistry of 2-pyrrolidino-1,4-benzoquinone **3** it is not necessary to postulate **19** in the elimination of phenolate groups, since the formation of the phenols can be accommodated satisfactorily by elimination from the benzoxazoline photoproducts **4**. Unclear is the mechanism for elimination of carboxylate leaving groups to form ortho-quinone methide **5,** since the elimination could occur either from **19** or **4**. No evidence could be obtained to support the direct elimination of carboxylate leaving groups from **19** using nanosecond laser flash photolysis methods.

If the unobserved benzoxazolines **4** ($LG^- = PhCH_2CO_2^-$, $PhCO_2^-$, and $4\text{-}CNC_6H_4CO_2^-$) are produced upon photolysis of **3**, one can predict the release rates of the carboxylate groups from the Figure 3 plot of log k vs -pK_a, which pertains to eliminations of phenolate leaving groups at 17 °C. Extrapolation of the data to the respective carboxylates gives release times of 115, 89, and 20 ms.

The estimated release times for carboxylate leaving groups assume that the para-substituted phenolate leaving groups and the carboxylate leaving groups lie on the same Bronsted-type correlation line in the plot of log k vs $-pK_a$. Both phenols and carboxylic acids are well-correlated in Bronsted plots for general acid-catalyzed dehydration of acetaldehyde hydrate[20] and as conjugate bases in proton transfer from acetylacetone.[21] More diverse bases are correlated in Bronsted plots for general base-catalyzed deprotonation of ethyl nitroacetate[22a] and detritiation of *tert*-butylmalononitrile-1-*t*.[22b] Nevertheless, correlations involving different chemical classes of acids or bases can be a source of scatter in Bronsted-type plots,[23] and therefore, the

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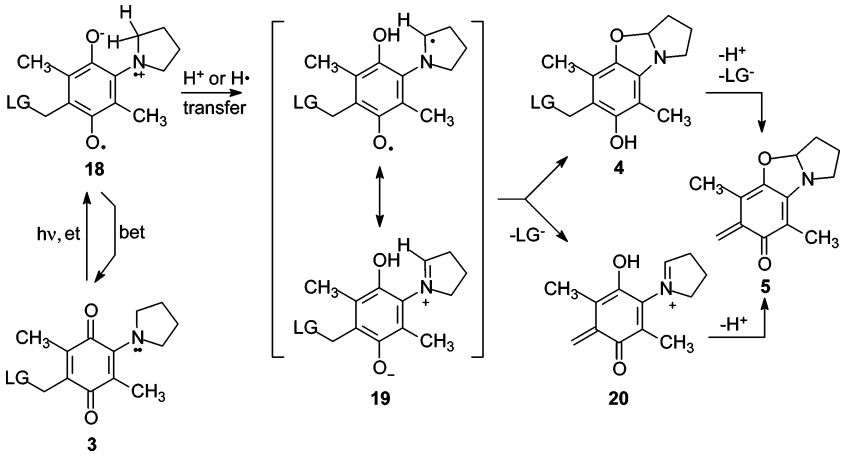
SCHEME 4



release times for carboxylates leaving groups, as predicted from the Bronsted-type plot for elimination of para-substituted phenolates (Figure 3), will be subject to unknown error, because the carboxylate and phenolate leaving groups are dissimilar leaving group bases.

Conclusion

2-Pyrrolidino-1,4-benzoquinones **3** photocyclize to benzoxazolines **4** upon exposure to visible light in the 450−650 nm wavelength region. Quantum efficiencies decrease with increasing solvent polarity, consistent with significant intramolecular charge transfer character in the initial excited state. Benzoxazoline photoproducts with acyloxymethyl or phenoxymethyl substitution at the C-7 position are unstable with respect to elimination of the carboxylate or phenolate leaving groups in aqueous media at neutral or basic pH. Carboxylate groups are expelled rapidly to form an ortho-quinone methide intermediate, whereas with a less labile phenolate leaving group the benzoxazoline is observed to build up as a photoproduct under aqueous conditions and can be isolated after photolyses of **3** (LG^- = 4-$YC_6H_4O^-$, Y = H, CF_3, CN) performed in nonhydroxylic solvents. Rate constants for elimination of para-substituted phenolate leaving groups from benzoxazolines give linear plots of log *k* vs -pK_a in aqueous media under buffered conditions.

Experimental Section

Preparation of 2-Hydroxy-5-methoxy-3,6-dimethylbenzaldehyde (8). The procedure was similar to one reported in the literature.[7] To a mixture of 5.0 g (32.8 mmol) of 2,5-dimethyl-4-methoxyphenol[8] in 300 mL of CH_3CN (distilled over CaH_2) containing 13 mL (93.3 mmol) of triethylamine and 9.8 g (103 mmol) of anhydrous $MgCl_2$ was added 3.5 g (117 mmol) of dry paraformaldehyde in portions. The mixture was refluxed for 8 h and cooled, 5% aqueous HCl was added, and the mixture was extracted with ether. The extracts were dried over $MgSO_4$ and concentrated in vacuo, and the residue was purified by medium-pressure liquid chromatography on 230−400 mesh silica gel (MPLC), eluting with 10% EtOAc in hexane. This gave 3.67 g (62% yield) of yellow crystals, mp 94.5−95.5 °C. The spectral data were as follows: ^{1}H NMR ($CDCl_3$) δ 2.20 (s, 3 H), 2.42 (s, 3 H), 3.76 (s, 3 H), 6.98 (s, 1 H), 10.29 (s, 1 H), 11.73 (s, 1 H); ^{13}C NMR ($CDCl_3$) δ 9.8, 15.6, 57.3, 118.1, 123.8, 124.5, 126.9, 149.4, 155.5, 195.9.

Preparation of 2-Hydroxy-5-methoxy-3,6-dimethylbenzenemethanol (9). The procedure was similar to one reported in the literature.[24] To a solution of 2.0 g (11 mmol) of benzaldehyde **8** in 20 mL of glacial acetic acid was added 1.7 g (44 mmol) of solid $NaBH_4$ in portions with cooling to 16−21 °C. After 2 h, 10 mL of water was added and the mixture was neutralized with aq $NaHCO_3$. The mixture was extracted with ethyl acetate, and the extracts were dried over $MgSO_4$ and concentrated in vacuo. The solid residue was crystallized from 10% ethyl acetate in hexane to give 1.06 g (52% yield) of colorless crystals: mp 75.5−77.0 °C. The spectral data were as follows: ^{1}H NMR ($CDCl_3$) δ 2.02 (s, 3 H), 2.18(s, 3 H), 3.24(s, broad, 1 H), 3.73 (s, 3 H), 4.79 (s, 2 H), 6.58 (s, 1 H), 7.57 (s, broad,1 H); ^{13}C NMR($CDCl_3$) δ 11.5, 16.8, 56.7, 60.8, 113.5, 121.7, 122.5, 123.8, 148.2, 150.6. Anal. Calcd for $C_{10}H_{14}O_3$: C, 65.92; H, 7.74. Found: C, 65.81; H, 7.57.

Preparation of 2-Hydroxymethyl-3,6-dimethyl-2,5-cyclohexadiene-1,4-dione (10). A procedure similar to one in the literature was followed.[25] To 2.0 g (1.0 mmol) of 2-hydroxy-5-methoxy-3,6-dimethylbenzenemethanol **9** in 10 mL of CH_3CN was added dropwise, with stirring, a solution of 18.0 g (33.0 mmol) $Ce(NH_4)_2(NO_3)_6$ in 100 mL of deionized water with cooling in an ice bath. After being stirred overnight at room temperature, the mixture was extracted with $CHCl_3$, washed with saturated NaCl, dried over $MgSO_4$, and concentrated in vacuo. MPLC of the residue, eluting with 50% EtOAc in hexane, gave crystalline product, which was crystallized from 10% EtOAc in hexane to obtain 1.63 g (63%) of yellow crystals, mp 52.0−53.5 °C. The spectral data were as follows: ^{1}H NMR ($CDCl_3$) δ 2.02 (d, J = 1.5 Hz, 3 H), 2.06 (s, 3 H), 4.53 (s, 2 H), 6.59 (q, J = 1.5 Hz, 1 H); ^{13}C NMR ($CDCl_3$) δ 11.8, 15.9, 57.5, 133.6, 140.7, 142.1, 145.5, 187.7, 188.6. Anal. Calcd for $C_9H_{10}O_3$: C, 65.05; H, 6.07. Found: C, 64.72; H, 6.11.

Preparation of 2-Hydroxymethyl-3,6-dimethyl-5-pyrrolidino-2,5-cyclohexadiene-1,4-dione (6). A procedure similar to one reported in the literature was followed.[1b] To 1.5 g (9.0 mmol) of 2-hydroxymethyl-3,6-dimethyl-2,5-cyclohexadiene-1,4-dione **10** in 100 mL of CH_2Cl_2 was added dropwise with stirring a solution of 1.5 mL (18.0 mmol) of pyrrolidine in 20 mL of CH_2Cl_2 with cooling in an ice bath, while keeping the reaction in the dark. After 3 h at room temperature, the volatiles were removed in vacuo. MPLC of the residue, eluting with 50% EtOAc in hexane, gave 1.42 g (67%) of the purple product as a viscous oil. The spectral data were as follows: ^{1}H NMR ($CDCl_3$) δ 1.84 (m, 4 H), 1.94 (s, 3 H), 1.98 (s, 3 H), 3.40 (s, broad, 1 H), 3.63 (m, 4 H), 4.47 (s, 2 H); ^{13}C NMR ($CDCl_3$) δ 11.4, 12.9, 26.0, 53.4, 59.0, 111.3, 136.7, 141.0, 151.0, 186.9, 187.8.

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Preparation of Carboxylate Derivatives 3 ($LG^- = PhCO_2^-$, $PhCH_2CO_2^-$, $4\text{-}CNC_6H_4CO_2^-$) of 2-Hydroxymethyl-3,6-dimethyl-5-pyrrolidino-2,5-cyclohexadiene-1,4-dione. To a solution of 40 mmol of 2-hydroxymethyl-3,6-dimethyl-5-pyrrolidino-2,5-cyclohexadiene-1,4-dione **6** in 100 mL of CH_2Cl_2 in an ice bath was added dropwise with stirring a solution of 80 mmol of acid chloride in 20 mL of CH_2Cl_2. The mixture was stirred at room temperature for 10−30 h, depending on the ester to be synthesized. In each case, the mixture was washed with 5% aq HCl and satd NaCl, dried over $MgSO_4$, and concentrated in vacuo. MPLC of the residue, eluting with 30% EtOAc in hexane gave each ester product as purple crystals, generally in 70−80% yields.

The spectral data for 2-[(benzoyloxy)methyl]-3,6-dimethyl-5-(1-pyrrolidino)-2,5-cyclohexadiene-1,4-dione **3** ($LG = PhCO_2^-$) were as follows: ^{1}H NMR ($CDCl_3$) δ 1.85 (m, 4 H), 2.03 (s, 3 H), 2.08 (s, 3 H), 3.63 (m, 3 H), 5.26 (s, 4 H), 7.38 (t, J = 7.2 Hz, 2 H), 7.51 (t, J = 7.2 Hz, 1 H), 798 (d, J = 7.2 Hz, 2 H); ^{13}C NMR ($CDCl_3$) δ 12.8, 13.5, 26.1, 53.3, 58.5, 112.1, 128.4, 129.8, 129.9, 133.1, 137.1, 141.1, 150.3, 166.3, 183.9, 187.4; absorption (30% aq CH_3CN) λ_{max} 542 nm (ϵ 3150 M^{-1} cm^{-1}). Anal. Calcd for $C_{20}H_{21}O_4N$: C, 70.78; H, 6.24; N, 4.13; Found: C, 70.88; H, 6.35; N, 4.12.

The spectral data for 2-[(phenylacetyloxy)methyl]-3,6-dimethyl-5-(1-pyrrolidino)-2,5-cyclohexadiene-1,4-dione **3** ($LG = PhCH_2CO_2^-$) were as follows: ^{1}H NMR ($CDCl_3$) δ 1.85 (m, 4 H), 1.92 (s, 3 H), 2.02 (s, 3 H), 3.60 (s, 2 H), 5.03 (s, 2 H), 7.25 (m, 5 H); ^{13}C NMR ($CDCl_3$) δ 12.3, 13.4, 26.1, 41.3, 53.3, 58.5, 112.2, 127.2, 128.6, 129.4, 133.89, 136.90, 141.1, 171.3, 183.9, 187.3; absorption (30% aq CH_3CN) λ_{max} 542 nm (ϵ 2850 M^{-1} cm^{-1}). Anal. Calcd for $C_{21}H_{23}O_4N$: C, 71.37; H, 6.56; N, 3.96. Found: C, 71.17; H, 6.51; N, 3.84.

The spectral data for 2-[(4-cyanobenzoyloxy)methyl]-3,6-dimethyl-5-(1-pyrrolidino)-2,5-cyclohexadiene-1,4-dione **3** ($LG = 4\text{-}CNC_6H_4CO_2^-$) were as follows: ^{1}H NMR ($CDCl_3$) δ 1.86 (m, 4 H), 2.03 (s, 3 H), 2.08 (s, 3 H), 3.64 (m, 4 H), 5.28 (s, 2 H), 7.07 (d, J = 8.7 Hz, 2 H), 8.10 (d, J = 8.6 Hz, 2 H); ^{13}C NMR ($CDCl_3$) δ 12.5, 13.4, 26.1, 53.4, 59.2, 112.0, 116.5, 118.1, 130.3, 132.3, 133.8, 136.5, 141.4, 150.4, 164.7, 183.8, 187.2; absorption (30% aq CH_3CN) λ_{max} 542 nm (ϵ 2990 M^{-1} cm^{-1}). Anal. Calcd for $C_{21}H_{20}O_4N_2O_4$: C, 69.22; H, 5.53; N, 7.69. Found: C, 68.97; H, 5.58; N, 7.59.

Preparation of 4-Cyanophenolate Derivative 3 ($LG^- = 4\text{-}CNC_6H_4O^-$) of 2-Hydroxymethyl-3,6-dimethyl-5-pyrrolidino-2,5-cyclohexadiene-1,4-dione. The procedure followed one reported previously.[26] To a solution of 71.5 mg (0.60 mmol) of 4-cyanophenol, 0.10 g (0.43 mmol) of 2-hydroxymethyl-3,6-dimethyl-5-pyrrolidino-2,5-cyclohexadiene-1,4-dione **6**, and 0.21 g (0.80 mmol) of Ph_3P in 5 mL of dry DMF was added 139 mg (0.13 mL, 0.80 mmol) of diethyl azodicarboxylate dropwise via pipet under nitrogen while cooling in an ice bath. The mixture was stirred overnight. The mixture was concentrated in vacuo, and 20 mL of ethyl acetate was added along with 20 mL water. The phases were separated, and the aqueous was extracted twice with ethyl acetate. The combined organic phases were dried over Na_2SO_4 and concentrated in vacuo. MPLC of the residue, eluting with 10% ethyl acetate in hexane, gave 53 mg (37% yield) of NMR pure 4-cyanophenoxy derivative **3** ($LG^- = 4\text{-}CNC_6H_4O^-$) as a purple oil. The spectral data for 2,5-dimethyl-3-[(4-cyanophenoxy)methyl]-6-pyrrolidino-2,5-cyclohexadiene-1,4-dione **3** ($LG^- = 4\text{-}CNC_6H_4O^-$) were as follows: ^{1}H NMR (CD_3CN) δ 1.84 (m, 4 H), 2.00 (s, 3 H), 2.01 (s, 3 H), 3.63 (m, 4 H), 5.01 (s, 2 H), 7.08 (d, J = 9.0 Hz, 2 H), 7.65 (d, J = 9.0 Hz, 2 H).

Preparation of 4-Trifluoromethylphenolate Derivative 3 ($LG^- = 4\text{-}CF_3C_6H_4O^-$) of 2-Hydroxymethyl-3,6-dimethyl-5-pyrrolidino-2,5-cyclohexadiene-1,4-dione. The same procedure as for **3** ($LG^- = 4\text{-}CNC_6H_4O^-$) was followed to obtain 54 mg (33% yield) of NMR pure compound **3** ($LG^- = 4\text{-}CF_3C_6H_4O^-$) as a purple oil. The spectral data for 2,5-dimethyl-3-[(4-trifluoromethylphenoxy)-methyl]-6-pyrrolidino-2,5-cyclohexadiene-1,4-dione **3** ($LG^- = 4\text{-}CF_3C_6H_4O^-$) were as follows: ^{1}H NMR (CD_3CN) δ 1.83 (m, 4 H), 2.01 (s, 3 H), 2.02 (s, 3 H), 3.63 (m, 4 H), 5.00 (s, 2 H), 7.08 (d, J = 9.0 Hz, 2 H), 7.61 (d, J = 9.0 Hz, 2 H); ^{13}C NMR (CD_3CN) δ 12.5, 13.2, 26.4, 53.9, 62.5, 111.4, 123.2 (q, J = 33 Hz), 125.7 (q, J = 272 Hz), 128.0 (q, J = 4 Hz), 137.6, 142.8, 152.2, 162.5, 184.5, 188.6.

General Procedure for Photolyses of Compound 1, 14, and 3 ($LG^- = PhCO_2^-$, $PhCH_2CO_2^-$, $4\text{-}CNC_6H_4CO_2^-$, PhO^-, $4\text{-}CF_3C_6H_4O^-$, and $4\text{-}CNC_6H_4O^-$). A tube containing 0.02−0.03 M **1**, **3**, or **14** in 30% H_2O in CH_3CN, CH_2Cl_2, or CH_3CN, mounted inside a Pyrex beaker, was irradiated with a 120 W sunlamp through the walls of the beaker, maintaining the sample at room temperature with a stream of air. Photolyses at 542 nm were conducted by photolyzing samples with light from a 200 W high-pressure mercury lamp, which was passed through a monochromator. Details of specific photolyses are given below.

Photolyses of 3,6-Dimethyl-2-pyrrolidino-2,5-cyclohexadiene-1,4-dione 1. A solution of 232 mg (1.1 mmol) of 2-pyrrolidino-1,4-benzoquinone **1** in 30 mL of CH_2Cl_2 was irradiated using the general photolyses procedure. The solvent was removed in vacuo. MPLC of the residue, eluting with 20% EtOAc in hexane, gave crystalline product, which was crystallized from 10% EtOAc in hexane to obtain 170 mg (73% yield) of cyclization product **2** as white crystals, mp 110.0−111.5 °C. The spectral data for 1,2,3,3a-tetrahydro-5,8-dimethylpyrrolo[2,1-b]benzoxazole **2** were as follows: ^{1}H NMR ($CDCl_3$) δ 1.87 (m, 2 H), 2.07 (s, 3 H), 2.14 (s, 3 H), 2.21 (m, 2 H), 2.97 (m, 1 H), 3.35 (m, 1 H), 5.15 (br s, 1 H), 5.81 (t, J = 3.3 Hz, 1 H), 6.61 (s, 1 H); ^{13}C NMR ($CDCl_3$) δ 10.8, 15.3, 24.2, 32.8, 55.8, 102.8, 110.8, 111.1, 115.2, 140.5, 145.0, 148.3.

Photolyses of 2,6-Dichloro-5-methyl-3-pyrrolidino-2,5-cyclohexadiene-1,4-dione 14. Irradiation of 16 mg of **14** in 0.45 mL of CD_2Cl_2 in a NMR tube to 100% conversion produced NMR pure 1,2,3,3a-tetrahydro-5,7-dichloro-8-methylpyrrolo[2,1-*b*]benzoxazole **15**. The yield was 100%, determined by NMR using a known amount of DMSO as a NMR standard. The spectral data for **15** were as follows: ^{1}H NMR ($CDCl_3$) δ 1.86 (m, 2 H), 2.15(s, 3 H), 2.22 (m, 2 H), 3.18 (m, 1 H), 3.38 (m, 1 H), 5.51 (br s, 1 H), 5.89 (m, 1 H).

Photolysis of 2-[(Benzoyloxy)methyl]-3,6-dimethyl-5-(1-pyrrolidino)-2,5-cyclohexadiene-1,4-dione 3 ($LG^- = PhCO_2^-$). Irradiation of 0.43 g (1.3 mmol) of **3** ($LG = PhCO_2^-$) in 50 mL of 30% aq CH_3CN to 100% conversion produced adduct **11** as a ca. 1:1 mixture of diastereomers. The solution was extracted with ethyl acetate. Adduct **11** was separated by MPLC, eluting with 20% ethyl acetate in hexane, to obtain 0.25 g (36% yield) of a viscous oil. The spectral data for **11** were as follows (nonoverlapping minor diastereomer peaks in parentheses): ^{1}H NMR ($CDCl_3$) δ 1.40 (s, 3 H), 1.44 (s, 3 H), 1.68 (m, 8 H), 1.86 (s, 6 H), 1.85 (m, 4 H), 2.13 (s, 3 H), 2.15 (s, 3 H), 2.17 (m, 4 H), 2.19 (s, 3 H), 2.20 (s, 3 H), 2.45 (m, 2 H), 2.73 (m, 6 H), 2.88 (m, 4 H), 2.99 (m, 2 H), 3.34 (m, 2 H), 5.23 (d, J = 12 Hz, 2 H), 5.32 (d, J = 12 Hz, 2 H), 5.76 (m, 2 H), 7.41 (t, J = 7.8 Hz, 4 H), 7.54 (t, J = 7.8 Hz, 2 H), 7.95 (d, J = 7.8 Hz, 4 H); ^{13}C NMR ($CDCl_3$) δ 10.7 (10.6), 11.6, 13.2 (13.1), 17.9 (17.8), 24.1, 25.0 (24.9), 32.61 (32.58), 36.6, 48.0 (47.9), 52.3 (52.0), 55.9 (55.8), 58.6, 94.94 (94.92), 102.6, 110.9 (110.8), 112.0 (111.8), 112.5, 128.7, 129.8, 133.5, 138.98 (138.96), 139.3, 145.0 (144.8), 145.6 (145.5), 146.9 (146.7), 166.2, 193.8 (193.4), 199.1. Anal. Calcd for $C_{33}H_{36}N_2O_6$: C, 71.15; H, 6.52; N, 5.03. Found: C, 70.76; H, 6.58; N, 4.99.

Photolysis of 2-[(Benzoyloxy)methyl]-3,6-dimethyl-5-(1-pyrrolidinyl)-2,5-cyclohexadiene-1,4-dione 3 ($LG^- = PhCO_2^-$) with 3-(Dimethylamino)cyclohexen-1-one 12 as Trapping Reagent. Irradiation of 0.35 g (1.0 mmol) of **3** ($LG = PhCO_2^-$) in 50 mL of 30% aq CH_3CN with 0.1 M 3-(dimethylamino)cyclohexen-1-one **12** to 100% conversion produced cycloadduct **13**. The solution was extracted with ethyl acetate. Cycloadduct **13** was separated by

(26) Kraus, G. A.; Zhang, N. *J. Org. Chem.* **2000**, 65, 5644−5646.

MPLC, eluting with 20% ethyl acetate in hexane, to obtain 0.30 g (87% yield) of crystalline solid, mp 194−196 °C. Cycloadduct **13** was characterized by NMR spectroscopy, elemental analysis, and X-ray crystallography. The spectral data for **13** were as follows: ^{1}H NMR ($CDCl_3$) δ 1.08 (s, 3 H) 1.09 (s, 3 H) 1.86 (m, 2 H) 2.05 (s, 3 H) 2.16 (s, 3 H) 2.21 (m, 2 H) 2.29 (s, 2 H) 2.39 (s, 2 H) 2.93 (m, 1 H) 3.24 (m, 2 H) 3.34 (m, 1 H) 5.79 (m, 1 H); ^{13}C NMR ($CDCl_3$) δ 10.8, 11.7, 20.1, 24.1, 28.6, 32.4, 32.7, 41.6, 50.9, 56.0, 102.9, 107.7, 111.5, 113.9, 114.4, 138.8. Anal. Calcd for $C_{21}H_{25}NO_3$: C, 74.31; H, 7.42; N, 4.13. Found: C, 74.28; H, 7.56; N, 4.20.

Photolysis of 2,5-Dimethyl-3-phenoxymethyl-6-pyrrolidino-2,5-cyclohexadiene-1,4-dione 3 (LG$^-$ = PhO$^-$). A solution of 15 mg (0.048 mmol) of **3** (LG$^-$ = PhO$^-$) in 0.45 mL of CD_3CN in an NMR tube was irradiated following the general procedure to obtain NMR-pure cyclization compound, 1,2,3,3a-tetrahydro-5,8-dimethyl-7-phenoxymethylpyrrolo[2,1-*b*]benzoxazole **4** (LG$^-$ = PhO$^-$). The yield was 100%, determined by NMR using a known amount of DMSO as a NMR standard. The spectral data were as follows: ^{1}H NMR (CD_3CN) δ 1.84 (m, 2 H), 2.09 (s, 3 H), 2.12 (s, 3 H), 2.22 (m, 2 H), 2.99 (m, 1 H), 3.32 (m,1 H), 5.03 (d, 2 H), 5.76 (m,1 H), 6.03 (br s, 1H), 6.95 (t, J = 7.2 Hz, 1 H), 7.00 (d, J = 7.2 Hz, 2 H), 7.30 (t, J = 7.2 Hz, 2 H); ^{13}C NMR (CD_3CN) δ 11.5, 12.0, 24.5, 33.3, 56.2, 63.5, 103.3, 111.9, 115.6, 115.7, 116.9, 121.6, 130.5, 141.9, 146.1, 149.2, 159.9.

Photolyses of 2,5-Dimethyl-3-[(4-trifluoromethylphenoxy)-methyl]-6-pyrrolidino-2,5-cyclohexadiene-1,4-dione 3 (LG$^-$ = 4-CF$_3$C$_6$H$_4$O$^-$). Irradiation of 10.1 mg (0.030 mmol) of **3** (LG = 4-$CF_3C_6H_4O^-$) in 0.45 mL of CD_3CN in a NMR tube to 100% conversion produced NMR pure cyclization compound, 1,2,3,3a-tetrahydro-5,8-dimethyl-7-[(4-trifluoromethylphenoxy)methyl]pyrrolo-[2,1-*b*]benzoxazole **4** (LG$^-$ = 4-$CF_3C_6H_4O^-$). The yield was 100%, determined by NMR using a known amount of DMSO as a NMR standard. The spectral data were as follows: ^{1}H NMR (CD_3CN) δ 1.83 (m, 2 H), 2.11(s, 3 H), 2.15 (s, 3 H), 2.05 (m, 1 H), 3.02(m,1 H), 3.35 (m, 1H), 5.12 (m, 2H), 5.79(m, 1H) 6.04 (s, 1H), 7.16 (d, J = 8.4 Hz, 2 H), 7.64 (d, J = 8.4 Hz, 2 H); ^{13}C NMR (CD_3CN) δ 11.5, 11.9, 24.5, 33.3, 56.2, 63.9, 103.4, 111.9, 115.9, 116.4, 116.6, 122.3 (q, J = 32 Hz), 125.8 (q, J = 271 Hz), 127.9 (q, J = 4 Hz), 142.2, 146.2, 149.2, 162.9.

Photolyses of 2,5-Dimethyl-3-[(4-cyanophenoxy)methyl]-6-pyrrolidino-2,5-cyclohexadiene-1,4-dione 3 (LG$^-$ = 4-CNC$_6$H$_4$O$^-$). Irradiation of 11.4 mg (0.034 mmol) of **3** (LG = 4-$CNC_6H_4O^-$) in 0.45 mL of CD_3CN in an NMR tube to 100% conversion produced NMR-pure cyclization compound 1,2,3,3a-tetrahydro-5,8-dimethyl-7-[(4-cyanophenoxy)methyl]pyrrolo[2,1-*b*]benzoxazole **4** (LG$^-$ = 4-$CNC_6H_4O^-$). The yield was 100%, determined by NMR using a known amount of DMSO as a NMR standard. The spectral data were as follows: ^{1}H NMR (CD_3CN) δ 1.83 (m, 2 H), 2.05 (m, 1H) 2.08 (s, 3 H), 2.12 (s, 3 H), 2.21 (m, 1 H), 5.10 (m, 1H), 5.77 (m, 1H) 6.00 (s, 1H), 7.12 (d, J = 9.0 Hz, 2 H), 7.65 (d, J = 9.0 Hz, 2H).

General Procedure for Product Quantum Yield Determinations. The quantum yields were determined with a semi-micro-optical bench apparatus that was similar to that described by Zimmerman.[27] Light from a 200 W high-pressure mercury lamp was passed through an Oriel monochromator, which was set to 542 nm wavelength, and collimated through a lens. A fraction of the light was diverted 90° by a beam splitter to a 10 cm × 3.6 cm side quartz cylindrical cell containing actinometer. The photolysate was contained in a 10 cm × 1.8 cm quartz cylindrical cell of 25 mL volume. Behind the photolysate was mounted a quartz cylindrical cell containing 25 mL of actinometer. Light output was monitored by ferrioxalate actinometry[28] using the splitting ratio technique. To ensure that all of the 458 nm light was absorbed, the concentration of the Fe^{3+} in the actinometer solution was increased to 0.0154 M, as prescribed by the literature.[29] A third cell mounted behind the main cell (in-line with the light beam) showed that all of the 458 nm light was always absorbed by the actinometer in the main cell. The quantum yield was taken to be $\Phi_{Fe^{2+}} = 1.09$.[29] The product yields were determined by ^{1}H NMR or HPLC analyses, and absorption spectroscopy was used to monitor disappearance of starting material.

General Procedure for Low-Temperature Photolyses. A 5 × 10^{-4} M solution of **3** (LG = $PhCO_2^-$) in 30% aq CH_3CN or in 30% phosphate buffer in CH_3CN at pH 7 was placed in a cell that was mounted inside a Dewar, which had windows that allowed photolyses to be conducted using a sunlamp or 542 nm light passed through a monochromator. The temperature was maintained at 2 °C during photolysis with an ice bath. The purple color of **3** disappeared after 30 min. The ice bath was replaced by water, the sample was warmed to 20 °C in 3 min, and the absorption spectrum was obtained at 10 min time intervals.

General Procedure for Release Rate Determinations. Solutions of 10−15 mg (ca. 0.04 mmol) of **3** (LG = PhO$^-$, 4-$CNC_6H_4O^-$, 4-$CF_3C_6H_4O^-$) in 0.4−0.5 mL of CD_2Cl_2 in an NMR tube were irradiated using the general photolysis procedure. After the purple color of **3** disappeared, the solvent was removed in vacuo and 0.4−0.5 mL of 30% phosphate buffer in CD_3CN (pD 7) was added along with a standard amount of DMSO. The ^{1}H NMR spectrum was then obtained at certain time intervals to monitor the decay of photoproduct **4**, while maintaining the sample at 17 °C in the dark.

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Supporting Information Available: Synthesis procedures of 2,5-dimethoxy-3,6-dimethylbenzenemethanol, 1-chloro-2,5-dimethoxy-3,6-dimethylbenzene, 1-phenoxy-2,5-dimethoxy-3,6-dimethylbenzene, 2,6-dimethyl-3-phenoxymethyl-2,5-cyclohexadiene-1,4-dione, **3** (LG$^-$ = PhO$^-$), **14**, and **17**. NMR spectral data for **2**, **3** (LG$^-$ = $PhCO_2^-$, $PhCH_2CO_2^-$, 4-$CNC_6H_4CO_2^-$, PhO$^-$, 4-$CNC_6H_4O^-$, 4-$CF_3C_6H_4O^-$), **4** (PhO$^-$, 4-$CNC_6H_4O^-$, 4-$CF_3C_6H_4O^-$), **6**, **8**−**10**, **11** (LG$^-$ = $PhCO_2^-$), **13**−**15**, **17**, 2,5-dimethoxy-3,6-dimethylbenzenemethanol, 1-chloro-2,5-dimethoxy-3,6-dimethylbenzene, 1-phenoxy-2,5-dimethoxy-3,6-dimethylbenzene, and 2,6-dimethyl-3-phenoxymethyl-2,5-cyclohexadiene-1,4-dione. X-ray structure of **13** and **14** and CIF files for **13** and **14**. This material is available free of charge via the Internet at http://pubs.acs.org.

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