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Photoenolization-Induced Oxirane Ring Opening in 2,5-Dimethylbenzoyl Oxiranes To Form Pharmaceutically Promising Indanone Derivatives

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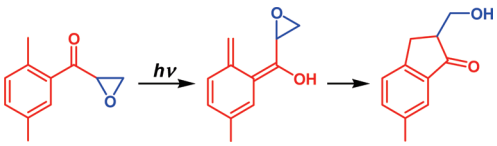

Irradiation of 2,5-dimethylbenzoyl oxiranes results in a relatively efficient and high-yielding formation of β-hydroxy functionalized indanones that structurally resemble biologically active pterosines. Nanosecond laser flash photolysis and quantum-chemical calculations based on density functional theory provided evidence that this photochemical transformation proceeds primarily via a photoenolization mechanism. Our study revealed considerable complexity of the mechanism and that structural modifications can significantly alter the reaction pathway and yield different products. The scope of this photochemical transformation for the synthesis of some pharmaceutically important compounds was investigated.

Introduction

Thermally as well as photochemically initiated cyclization reactions are important transformation steps in organic synthesis. It was demonstrated on many examples that the specific reactivity of the electronically excited states enables the formation of complex and highly functionalized molecules, thus shortening the number of synthetic steps.[1,2]

Triplet excited 2-alkylacetophenones are known to undergo intramolecular 1,5-hydrogen abstraction to form a triplet 1,4-biradical (triplet enol) and subsequently the two isomeric (*E*)- and (*Z*)-photoenols.[1,3−7] When the triplet pathway is completely suppressed, only the (*Z*)-enol is formed via the excited singlet state; this isomer is a short-lived species that readily reketonizes.[3] When a leaving group (LG) is present in the α-position of 2-alkylacetophenones, a longer-lived (*E*)-photoenol liberates the LG to give the corresponding cyclization (indanone, in red) or solvolysis (in blue) products (Scheme 1). This reaction, introduced by Bergmark,[8,9] was later utilized in the field of photoremovable protecting groups[10−14] by Klán, Wirz, and co-workers, who demonstrated that the 2,5-dimethylphenacyl (DMP) group can be used to protect moderately or good leaving groups, such as carboxylic acids,[15−17] phosphates, sulfonates,[18] alcohols as carbonates,[19] or amines as carbamates.[20]

Indanone derivatives are key intermediates in the synthesis of some pharmaceutically important compounds, such as the

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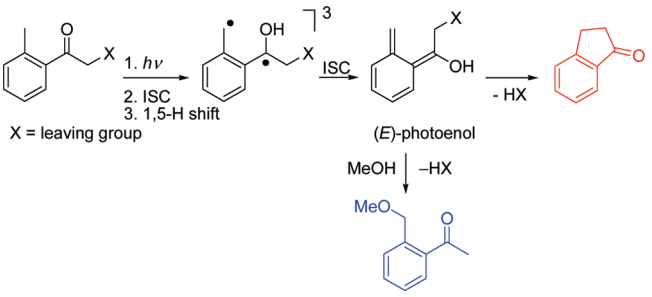
SCHEME 1. Photochemistry of *o*-Alkylphenacyl Derivatives

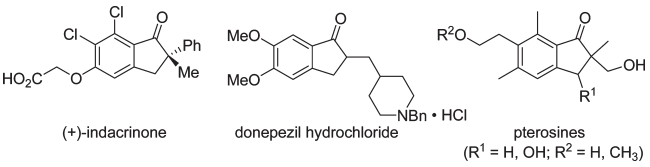


antihypertensive drug (+)-indacrinone,[21] the reversible acetylcholinesterase inhibitor donepezil hydrochloride,[22,23] and the antibacterial and cytotoxic pterosines (Chart 1).[24] For example, Wessig and co-workers used the phototransformation of 2-alkylacetophenone derivatives for the synthesis of two sesquiterpene indane derivatives, pterosine B or C,[25] and other indanone derivatives.[26] Klán and co-workers showed that photolysis of a 4,5-dimethoxyphenacyl derivative can lead to an indanone precursor for the synthesis of donepezil.[27] Wang and co-workers used this concept in polymer-supported synthesis,[28] and Park and co-workers utilized this reaction in photopolymerization[29] and the synthesis of various indanone and benzocyclobutenol derivatives.[30,31]

The synthesis of indanone building blocks using a photoenolization step is generally designed to start from precursors, which do not possess functional groups susceptible to photochemical side reactions and responsible for slowing down or impeding the initial 1,5-hydrogen abstraction step (Scheme 1). However, various functional groups are a part of the target indanones, such as those shown in Chart 1. Therefore, new photochemical transformations that would generate an indanone moiety possessing synthetically useful substituents in the corresponding positions are of considerable interest.

In this work we wish to report that, analogously to Scheme 1, various substituted indanone derivatives can be synthesized by photolysis of the 2,5-dimethylbenzoyl oxiranes **1** via the corresponding (*E*)-enol (Scheme 2). We expected that the initial 1,5-hydrogen abstraction step would efficiently compete with the α-C−O bond scission in the excited state and subsequent skeletal rearrangements, which are archetypal transformation

CHART 1. Biologically Active Indanone Derivatives



of benzoyl oxiranes.[32−40] Despite the fact that alkoxides (as poor leaving groups) are not liberated from the substituted *o*-alkylphenacyl derivatives,[19,20] we have also anticipated that the α-C−O bond in **1** will be broken upon cyclization of the corresponding (*E*)-enol to relieve internal strain of a three-membered ring. This would eventually yield 2-hydroxymethylindan-1-one related, for example, to the pterosine derivatives (Chart 1). Since many reliable strategies for the preparation of benzoyl oxiranes (epoxy ketones), including some of a very high enantiomeric purity,[41] are available, this strategy would be synthetically beneficial. We report on the synthesis of benzoyl oxiranes, their photochemical behavior, laser flash photolysis experiments, and some quantum chemical calculations. The possibility of utilizing the photoreaction of the benzoyl oxiranes in the synthesis of some structurally related pharmaceutically active compounds is considered.

Results and Discussion

Synthesis of 2,5-Dimethylbenzoyl Oxiranes. The 2,5-dimethylbenzoyl oxiranes **1a**−**d** (Scheme 3) were prepared to study their photochemical transformations. The synthesis started with the Friedel−Crafts acylation of *p*-xylene (**2**) to give **3a**,**c**,**d** and **4b**, followed by the aldol condensation−elimination (**4a**) or Mannich (**4c**,**d**) reactions to introduce a C=C bond. The subsequent nucleophilic epoxidation with aq H_2O_2 in methanol provided the target epoxy ketones **1a**−**d** in high overall yields (73−84%) and purity.

Photochemistry of 1a−d. A degassed acetonitrile solution of an epoxide (**1a**−**d**; ~5×10^{-3} M) was irradiated through a Pyrex filter (> 290 nm) until > 95% of the starting material was consumed. Three products, **5**−**7**, were isolated and identified (Scheme 4); the chemical yields are summarized in Table 1. In all cases, the indanones **5** were the major photoproducts at high conversions and essentially the sole photoproducts at conversions below 20%. The oxiranyl-ring-opening products **6** and the substituted 3,4-dihydrobenzo[*c*]oxepin-5(1*H*)-ones **7** were isolated only in the case of **1b** and **1d** and in very low chemical yields.

Exhaustive irradiation of **1c** afforded a complex mixture of compounds, from which only **5c** was successfully isolated in 7% yield. Since the HPLC yield at a 40% conversion was 82%, we assumed that this photoproduct underwent

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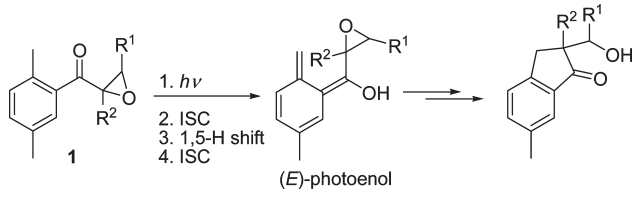
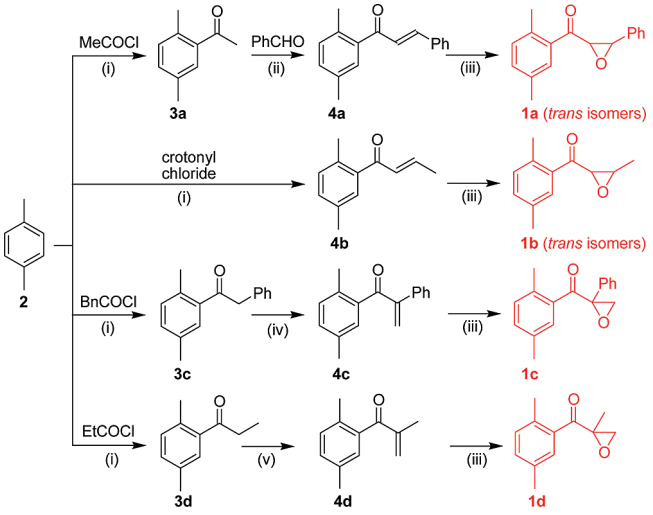
SCHEME 2. Photochemistry of *o*-Methylbenzoyl Oxiranes: The Strategy



SCHEME 3. Preparation of the Epoxides 1a−d[a]



[a]Reagents and conditions: (i) $AlCl_3$, CS_2, 0 °C; (ii) KOH, methanol, 20 °C; (iii) H_2O_2, KOH, MeOH, 0 °C; (iv) aq CH_2O, CH_3CO_2H (cat.), piperidine (cat.), MeOH; (v) aq CH_2O, morpholine (cat.), CH_3CO_2H.

SCHEME 4. Photochemistry of 1a−d

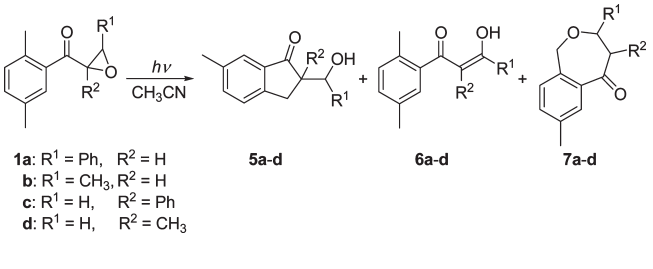


TABLE 1. Photochemical Formation of 5−7[a]

irradiated epoxide	% yield (**5a−d**)	% yield (**6a−d**)	% yield (**7a−d**)
1a	74[b,c] [93[d]]	n.d.[f]	n.d.[f]
1b	72[b,c] [85[d]]	7[b]	12[b]
1c	7[b] [82[e]]	n.d.[f]	n.d.[f]
1d	69[b] [93[d]]	8[b]	15[b]

[a]Degassed solutions of **1a−d** (~5×10^{-3} M) in acetonitrile were irradiated at $\lambda > 290$ nm to >95% conversion. [b]Isolated by column chromatography. [c]A pair of diastereomers in a ~1:1 ratio (NMR, HPLC). [d]The optimized HPLC yields of the indanone **5** formation in ~95% conversions. [e]The optimized HPLC yields of the indanone **5** formation in ~40% conversions. [f]Not detected.

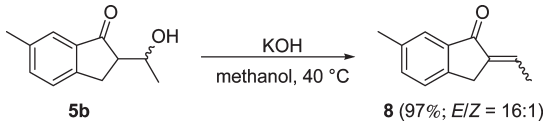
subsequent photochemical transformations. Indeed, prolonged irradiation of **5a** or **b** in acetonitrile led to a complex mixture of photoproducts, which were, however, produced with a lower efficiency than the primary photoproducts **5** formed from **1**.

TABLE 2. Quantum Yields (Φ) of 5a−d Formation from 1a−d

compound	Φ[a]
5a	0.11 ± 0.01
5b	0.15 ± 0.01 (0.16 ± 0.01[b])
5c	0.25 ± 0.01
5d	0.12 ± 0.01

[a]Degassed solutions (~5×10^{-3} M) in acetonitrile or benzene were irradiated at $\lambda = 313 \pm 5$ nm (optical bench). Φ was determined using valerophenone as an actinometer (Φ of acetophenone formation is 0.33 in hexane[42]). The results are based on at least five independent measurements; the relative standard deviations of the mean are shown. [b]Benzene solution.

SCHEME 5. Dehydration of 5b



The quantum yields of **5a−d** formation in acetonitrile (and benzene in the case of **5b**) are listed in Table 2. Their magnitude can be compared to that of the photorelease of carboxylate ions from the corresponding 2,5-dimethylphenacyl esters (Φ = 0.18−0.25) in benzene.[17] The quantum yields of LG release from 2,5-dimethylphenacyl chromophore are known to be generally higher in nonpolar solvents than in polar and protic solvents,[17−19] which was, however, not observed in the case of **1b** (Table 2).

Both **5a** and **5b** possess an α-hydrogen atom, which may allow elimination of water to form α,β-unsaturated ketones, useful intermediates in organic synthesis. Thus **5b** (~1×10^{-2} M) was heated in methanolic KOH (0.2 M) at 40 °C for 20 min, and **8** was isolated as a sole product in 97% yield as a mixture of (*E*)- and (*Z*)-diastereomers (~16:1; GC; Scheme 5). A more convenient one-pot procedure, in which a base is directly added to the reaction mixture that is irradiated, has been rejected because the product is a very reactive Michael reaction substrate (a complex mixture of products was obtained under such experimental conditions).

Mechanistic Studies. Initially we wished to determine the multiplicity of the excited state responsible for the photoproducts formation. Stern−Volmer analysis (see Supporting Information, S41) using naphthalene as a triplet quencher ($E_T = 60.5$ kcal mol^{-1})[43] revealed that the photoreaction of **1a** is fully quenched at high quencher concentrations ($c > 2$ M) and that the excited (triplet) state lifetime is ~2 ns, assuming that the energy transfer is diffusion-controlled ($k_q = 1.5 \times 10^9$ M^{-1} s^{-1} in benzene[43]). In addition, irradiation of **1b** in neat acetone, acting as a triplet sensitizer, afforded the same photoproducts as those obtained in acetonitrile by direct irradiation. We concluded that the photoproducts are exclusively triplet-state-derived. This is in agreement with the discussion of Park and his co-workers who studied a structurally analogous chromophore, 2-(*o*-tolyl)-2-benzoyloxirane (**9**, shown later in Scheme 7), the photochemistry of which also occurs exclusively from the triplet state.[44]

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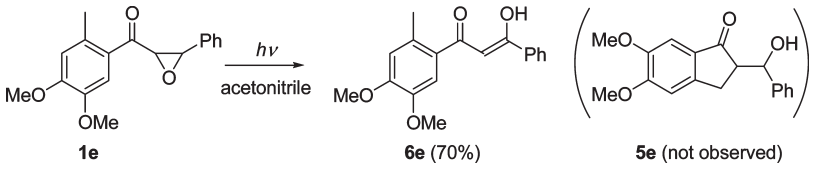
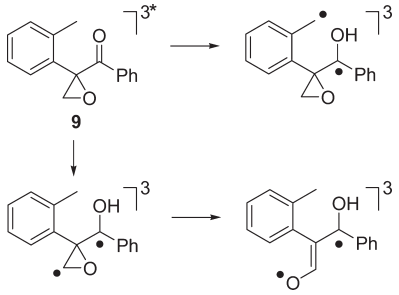
SCHEME 6. Irradiation of 1e



1e **6e** (70%) **5e** (not observed)

SCHEME 7. Photochemistry of 2-(*o*-Tolyl)-2-benzoyloxirane 9[44]



The phenacyl chromophore is known to have two nearly isoenergetic triplet states that differ in polarity, and their relative energies are strongly influenced by both the benzene ring substituents and the environment.[45] Electron-donating groups and polar solvents tend to stabilize the π,π^* state.[45−48] The π,π^* state of a phenyl ketone is generally far less reactive than the n,π^* state toward both electron and hydrogen-atom abstraction reactions.[49−52]

Because the major products obtained from photolysis of **1** were the indanones **5**, we assumed that they are produced via photoenolization initiated by an intramolecular 1,5-hydrogen abstraction (Scheme 1). The short lifetime of the triplet **1a** thus has to be related to an efficient intramolecular hydrogen abstraction, which furthermore implies that the state is n,π^* in character. The photochemistry of the epoxide **1e** was studied to confirm our assumption that the π,π^* excited epoxide will not produce the corresponding indanone **5e** (Scheme 6). Indeed, irradiation of a degassed solution of **1e** ($\sim 5 \times 10^{-3}$ M) at $\lambda > 290$ nm led to **6e** as a major product regardless of what kind of solvent (acetonitrile, benzene, hexane, *t*-BuOH) was used (Scheme 6). The two electron-donating methoxy groups in **1e** evidently inverted the energy of the two states, rendering the π,π^* state as the lowest (reactive) triplet state,[45,48] which resulted in a C_α−O bond scission.[34,38] The excited state type was theoretically examined on an analogue **1f** together with the unsubstituted *o*-methylbenzoyl oxirane **1g**. The relevant molecular orbitals from the UB3LYP/6-31G* level of theory in the gas phase are depicted in Figure 1. The results, according to which the lowest triplet states of **1f** and **1g** are of π,π^* and n,π^* character, respectively, are consistent with our assumption.

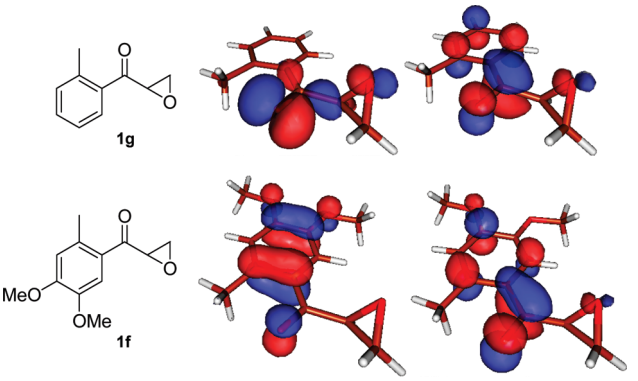


FIGURE 1. Highest occupied molecular orbitals (HOMO-1 and HOMO) of the triplet **1g** (n,π^*) and **1f** (π,π^*).

Formation of **6** and **7** (Schemes 4 and 6) suggests that a homolytic C_α−O bond scission[32−40] occurs at some stage of the reaction and competes with the 1,5-hydrogen atom shift. According to Park and co-workers,[44] only two competing chemical decay channels exist in the lowest triplet state of the analogous 2-(*o*-tolyl)-2-benzoyloxirane **9** (Scheme 7): a 1,4-H atom shift ($k = 6 \times 10^7\ s^{-1}$) from the methylene group of the oxiranyl ring followed, by the C_α−O bond scission and a 1,6-H atom shift ($k = 2.3 \times 10^8\ s^{-1}$) from the *o*-methyl group. Scheme 8 shows three reaction pathways of the triplet excited **1g** inspired by the photochemistry of **9** as obtained from our DFT quantum chemical calculations. As expected, the 1,5-H atom shift (preceding the photoenolization reaction) is preferred to the direct C_α−O bond homolysis by ~2 kcal mol^{-1}. The C_α−O bond was cleaved spontaneously in all of our attempts to locate the transition state of a 1,4-H atom shift in the triplet **1g**. Therefore, the C_α−O bond homolysis followed by a 1,4-H atom shift (highlighted in red, Scheme 8) is a dominant photochemical channel to **6**.

The rate constants of 1,5-H atom shift, which is observed in our system, are generally higher than those for less or more distant H-atom transfers due to the ring strain introduced in the transition state.[53−55] Indeed, the rates of both the 1,6-H atom shift ($\sim 2 \times 10^8\ s^{-1}$) and 1,4-H atom shift ($\sim 6 \times 10^7\ s^{-1}$) in **9** are slower than that of the 1,5-H atom shift in **1a** as estimated from the Stern−Volmer analysis ($\sim 5 \times 10^8\ s^{-1}$). The compound **6** was preferentially formed only when the inversion of the triplet state levels in **1e** decreased the rate constant of an H-atom abstraction (formation of the benzooxepinone **7e** was not observed).

A comprehensive reaction mechanism for the formation of **5** and **7** is demonstrated in Scheme 9 on the 2-methylbenzoyl oxirane **1g** photochemistry, which includes the results of our

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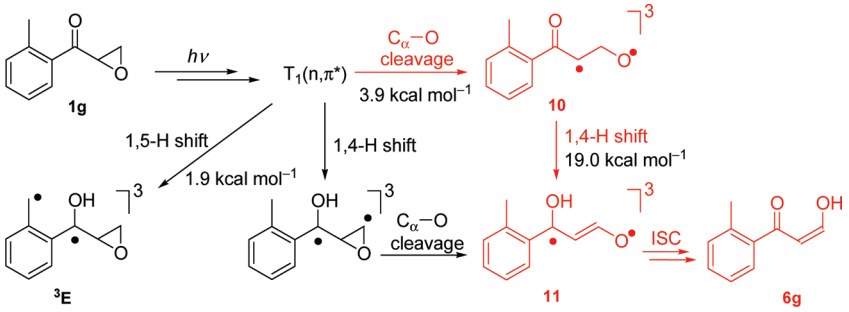
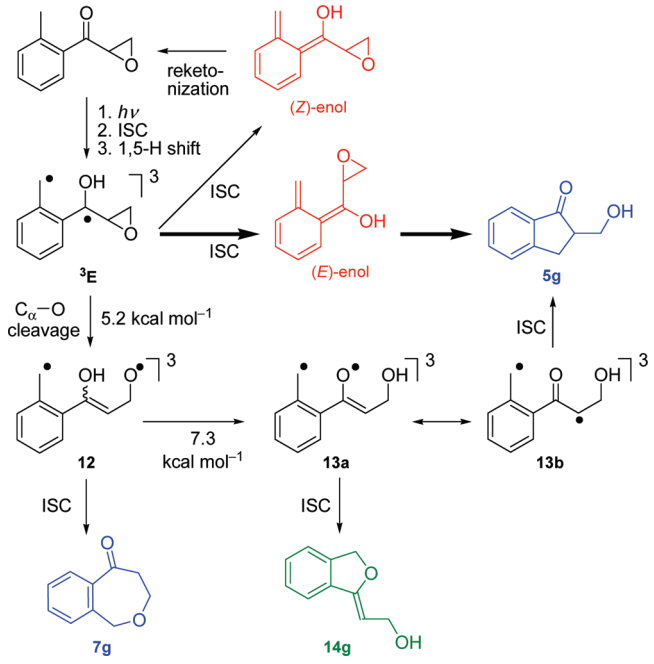
SCHEME 8. Formation of 6[a]



[a]The activation Gibbs energies are shown. The fate of ^{3}**E** is discussed later.

SCHEME 9. Formation of 5 and 7[a]



[a]Structures in blue and red denote isolated and spectroscopically observed species, respectively; a putative (not observed) product is shown in green. The operative pathway (vide infra) of the indanones formation is depicted by bold arrows. The activation Gibbs energies are shown.

DFT calculations. The primary 1,4-biradical ^{3}**E**, which was formed from the triplet excited compound by a hydrogen shift (Scheme 8), can undergo either C_α–O homolytic cleavage to **12** or intersystem cross to the ground state to produce two photoenols (in red). The rate of ^{3}**E** decay for phenacyl derivatives is known to depend on the presence of oxygen or other triplet quenchers (τ ~16–300 ns).[7,17,18,20] Compound **12** possesses a reactive primary alkoxy radical center; a simple H-atom shift between the two oxygen atoms with a calculated barrier of $\Delta G^{\ddagger} = 7.3$ kcal mol^{-1} results in a more stable radical (see Figure 2), whose two mesomeric forms, **13a** and **13b**, are shown in the scheme. This pathway can be considered as a spin-center shift mechanism, recently proposed by Wessig and co-workers.[56] Subsequent radical recombination and ISC may lead to **5g** or **14g** (in green). The spin population analysis favors the mesomeric form **13b** and the formation of **5g**. This is in agreement with our experiments because we found no evidence that **14** was formed by irradiation of **1**. In addition, the production of the benzooxepinones **7** (Table 1) suggests that a ring closure of **12** competes with a hydrogen shift to give **13b**. A complete triplet potential energy profile for the photochemistry of **1g**, calculated at the BMK/6-311+G(3df,2p) level of theory on B3LYP/6-31G* optimized geometries, is then depicted in Figure 2. Other reaction pathways known from the literature, such as α-cleavage to give the corresponding acyl and epoxy radicals,[32,57,58] heterolytic,[34] or electron-transfer mediated oxirane ring-opening[59] intermediates, are apparently not relevant for our systems.

Finally, we had to decide which of the two possible mechanisms for the formation of **5**, photoenolization or homolytic C_α–O bond scission in ^{3}**E**, are favored. Regeneration of the starting ketone from the (*E*)-photoenol requires a proton transfer through the solvent. When a suitable deuteron donor is present in the solution, the incorporation of deuterium into the *o*-methyl group can be detected by NMR measurements.[3] The *m*-methyl group signal in ^{1}H NMR spectra of **1a**–**d** interferes with those of the products. Therefore, epoxide **1h** (Scheme 10), having only a single methyl group, was synthesized and irradiated in a degassed D_2O/acetone-d_6 mixture (1:20) at >290 nm in an NMR cuvette. The ratio of the integrals, corresponding to the *o*-methyl and CH (of the oxiranyl ring) signals, decreased by ~25%. We were unable to integrate the peaks properly at longer irradiation times because of an overlap of the peaks with those of the products; nevertheless, it was sufficient evidence that photoenols are indeed formed in the solution upon irradiation.

In addition, the mechanism of the photoreactions of **1b** was investigated by laser flash photolysis (Table 3; see also Supporting Information, S41–44). The transient absorption spectrum of an aerated solution of **1b** in acetonitrile obtained 1 μs after the laser flash is shown in Figure 3. The absorption spectrum reproduces nicely that measured for both ground state photoenols in previous studies.[7,17–20] We were unable to see any significant absorption at ~340–350 nm characteristic of ^{3}**E** even at short time delays (15 ns). Such a remarkable short lifetime of a 1,4-biradical is consistent with that reported by Caldwell and co-workers for α-benzyloxyacetophenone[60] or

(56) Wessig, P.; Muehling, O. *Eur. J. Org. Chem.* **2007**, 2219.

(57) Dunston, J. M.; Yates, P. *Tetrahedron Lett.* **1964**, 505.
(58) Padwa, A. *Tetrahedron Lett.* **1964**, 813.
(59) Hasegawa, E.; Ishiyama, K.; Horaguchi, T.; Shimizu, T. *J. Org. Chem.* **1991**, *56*, 1631.

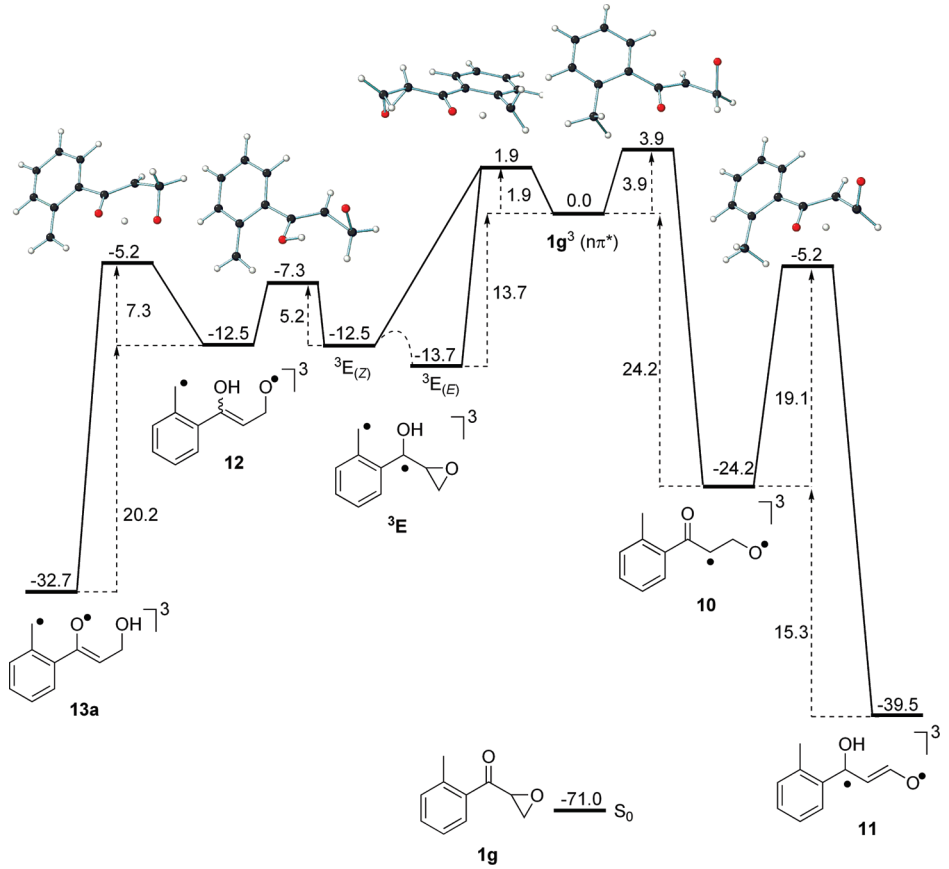


FIGURE 2. Triplet potential energy surface profile of **1g** photoreactions. The Gibbs energies (in kcal mol^{-1}) were calculated at the BMK/6-311+G(3df,2p) level of theory on B3LYP/6-31G* optimized geometries.

the 1,5-biradical in Scheme 7 found by Park et al.[44] A similar spectrum has been measured for **1a**. The kinetic trace at $\lambda = 390$ nm contained three exponential components: a very fast singly exponential rise and a biexponential decay. The lifetime of the former, short-lived component was sensitive to the presence of oxygen. Its lifetime of 23 ns in degassed solutions dropped to < 10 ns in air-saturated solutions, which we could not resolve because of limitations of our apparatus. However, the anticipated decrease of the rate constant for this component occurred in less polar cyclohexane: lifetimes of 47 and 12.5 ns were observed in the degassed and air-saturated solutions, respectively. This transient intermediate was assigned to the triplet enol (^{3}**E**) decay. The lifetimes of the other two components were not sensitive to the presence of oxygen. A shorter-lived intermediate with a lifetime of 8.8 and 2.8 μs in acetonitrile and cyclohexane solution, respectively, was attributed to the ground state (*Z*)-photoenol, which is expected to undergo fast intramolecular reketonization,[7,17] while the long-lived component was attributed to the (*E*)-photoenol. Its lifetime of 5.0 ms was observed in acetonitrile, whereas that in cyclohexane (> 40 ms) could not be fit properly because of instability of our white light source at such a long time scale. Our results resemble well those reported for the photoenolization in dimethylphenacyl chromophore substituted by different leaving groups in the α-position.[7,17−20]

Our assignments were also rationalized by performing TD-DFT calculations of the electronic transitions for all relevant intermediates shown in Figure 2. The results are summarized in the Supporting Information (S48). Only the photoenols and conformers of the triplet enol, ^{3}**E**, showed a strong absorption at ~390 nm (f ~0.15−0.19; Figure 3) and ~355−363 nm (f ~0.1), respectively. The transitions for other relevant species are approximately 10 times weaker in this region. Regarding the absence of significant spectral changes within the time of the experiment or in the presence of oxygen, we conclude that both kinetic traces assigned to the decay of the 390 nm signal belong to the photoenol intermediates, although the presence of some other relevant species cannot be unambiguously ruled out.

SCHEME 10. Deuterium Incorporation in 1h

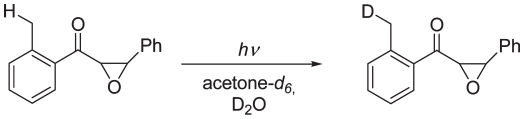


TABLE 3. Lifetimes τ of the Transients of 1b[a]

solvent	τ (^{3}**E**)	τ (*Z*)-photoenol	τ (*E*)-photoenol
acetonitrile	23 (< 10)[b] ns	8.8 μs	5 ms
cyclohexane	47 (12.5)[b] ns	2.8 μs	> 40 ms[c]

[a]Degassed solutions (~1 × 10^{-4} M) in acetonitrile or cyclohexane measured at $\lambda = 390$ nm after 266-nm laser flash. [b]The lifetimes measured for aerated solutions are in the parentheses. [c]The lower limit estimated from the exponential fit of the kinetic trace.

(60) Caldwell, R. A.; Majima, T.; Pac, C. *J. Am. Chem. Soc.* **1982**, *104*, 629.

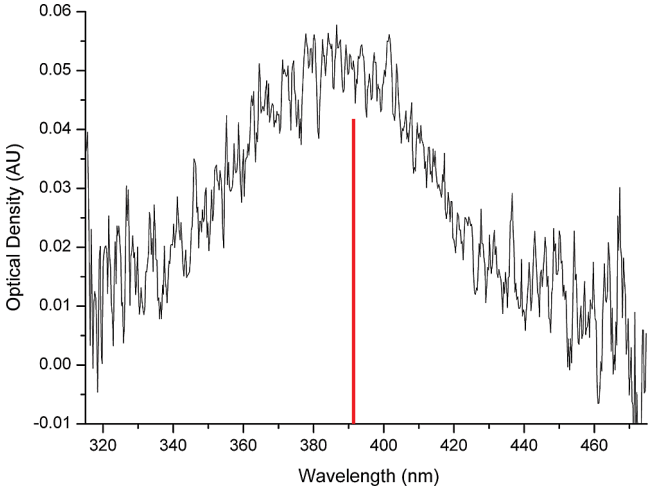


FIGURE 3. Transient absorption spectrum of **1b**. The spectrum was taken 1 μs after the laser flash for an acetonitrile solution of **1b**. The red line shows the TD-DFT calculated transition of the *E*-enol derived from **1g** (the intensity is arbitrarily scaled; see Supporting Information, S48).

In conclusion, four 2,5-dimethylbenzoyl oxiranes were synthesized in high overall chemical yields, and their photochemistry was explored. Irradiation of these epoxy ketones resulted in indanone derivatives as major products, which are structurally similar to some known pharmaceutically important compounds. In addition, a simple route to a 2-ethylidene-2,3-dihydro-1*H*-inden-1-one derivative from the synthesized indanones was described. The laser flash photolysis experiments and quantum-chemical calculations provided solid evidence that the indanone photoproducts are formed via a photoenolization mechanism. A total synthesis of several biologically active compounds, which is based on the photochemical approach introduced here, is currently under investigation in our laboratory.

Experimental Section

General Procedure for the Synthesis of Acylphenones 3a−e. The corresponding acyl chloride (224 mmol) was added dropwise to a mixture of aluminum chloride (27.2 g, 204 mmol) and either *p*-xylene (19.6 g, 185 mmol) or 1,2-dimethoxy-4-methylbenzene (28.2 g, 185 mmol) in CS_2 (100 mL) under nitrogen atmosphere at 0−3 °C in a period of 1.5 h. The reaction mixture was stirred for 1 h at 0 °C, warmed to 20 °C, stirred for additional 2 h, and then poured on ice (400 g). After the ice melted, the aqueous layer was extracted with CH_2Cl_2 (3 × 100 mL). The combined organic extracts were washed with brine (100 mL) and dried with $MgSO_4$. The solvent was evaporated under reduced pressure to give the crude title product, which was purified by vacuum distillation.

1-(2,5-Dimethylphenyl)ethanone (3a). Prepared from *p*-xylene and acetyl chloride (15.9 mL, 224 mmol). Yield: 95%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.35 (s, 3H), 2.47 (s, 3H), 2.55 (s, 3H), 7.10 (d, 1H, J = 7.8 Hz), 7.16 (d, 1H, J = 7.8 Hz), 7.47 (s, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 20.7, 20.8, 29.3, 129.7, 131.8, 132.0, 135.0, 135.6 137.6, 201.6. MS (EI, 70 eV): m/z = 148, 133, 105, 79, 77, 51, 43.

1-(2,5-Dimethylphenyl)-2-phenylethanone (3c). Prepared from *p*-xylene and phenylacetyl chloride (27.1 mL, 224 mmol). Yield: 95%; colorless crystals, mp 30.2−31.6 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.42 (s, 3H), 2.46 (s, 3H), 4.25 (s, 2H), 7.16 (d, 1H, J = 7.8 Hz,), 7.22 (dd, 1H, J_1 = 7.8 Hz, J_2 = 1.5 Hz), 7.31 (m, 3H, J = 7.0 Hz), 7.36 (d, 2H, J = 7.0 Hz), 7.58 (d, 1H, J = 1.5 Hz). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 20.8, 21.0, 48.4, 126.9, 128.6, 129.2, 129.6, 131.9, 132.1, 134.7, 135.1, 135.3, 137.8, 201.6. MS (EI, 70 eV): m/z = 224, 133, 105, 91, 77, 65, 51, 39.

1-(2,5-Dimethylphenyl)propan-1-one (3d). Prepared from *p*-xylene and propionyl chloride (17.8 mL, 224 mmol). Yield: 96%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 1.08 (t, 3H, J = 7.3 Hz), 2.22 (s, 3H), 2.34 (s, 3H), 2.75 (q, 2H, J = 7.3 Hz), 6.96 (d, 1H, J = 7.8 Hz), 7.01 (d, 1H, J = 7.8 Hz), 7.31 (s, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 8.0, 20.3, 20.4, 34.1, 128.5, 131.3, 131.4, 134.2, 134.7, 137.7, 204.1. MS (EI, 70 eV): m/z = 162, 133, 105, 91, 77, 65, 51, 41.

1-(4,5-Dimethoxy-2-methylphenyl)ethanone (3e). Prepared from 1,2-dimethoxy-4-methylbenzene and acetyl chloride (15.9 mL, 224 mmol). Yield: 84%; white crystals, mp 70.6−72.3 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.44 (s, 3H), 2.47 (s, 3H), 3.82 (s, 3H), 3.83 (s, 3H), 6.62 (s, 1H), 7.18 (s, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 21.8, 29.3, 55.8, 56.2, 113.4, 114.6, 129.4, 133.4, 146.3, 151.6, 199.4. MS (EI, 70 eV): m/z = 194, 179, 151, 136, 121, 108, 93, 77, 65, 43, 39.

(*E*)-1-(2,5-Dimethylphenyl)-3-phenylprop-2-en-1-one (4a). A solution of **3a** (2.00 g, 13.5 mmol) in ethanol (15 mL) was added dropwise to aq KOH (40 mL, 10%) at 0 °C. Freshly distilled benzaldehyde (1.43 g, 13.5 mmol) was then added dropwise to the mixture in the period of 10 min. The reaction mixture was stirred for 2 days at 20 °C and extracted with CH_2Cl_2 (3 × 50 mL). The organic extracts were washed with brine (50 mL), dried with $MgSO_4$, and solvents were evaporated at reduced pressure to give **4a**. Yield: 94%; yellowish oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.37 (s, 3H), 2.41 (s, 3H), 7.14 (d, 1H, J = 16.1 Hz), 7.18 (m, 2H), 7.30 (s, 1H), 7.41 (m, 3H), 7.48 (d, 1H, 1H, J = 16.1 Hz), 7.57 (m, 2H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 19.7, 20.9, 126.8, 128.4, 128.5, 128.8, 128.9, 130.5, 131.2, 133.7, 134.7, 135.0, 139.1, 145.6, 196.6. MS (EI, 70 eV): m/z = 236, 145, 131, 103, 77.

(*E*)-1-(2,5-Dimethylphenyl)but-2-en-1-one (4b). The compound was prepared from *p*-xylene (19.6 g, 185 mmol) and crotonyl chloride (21.2 g, 224 mmol) according to the procedure described for **3a−e**. Yield: 94%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 1.95 (dd, 3H, J_1 = 6.8 Hz, J_2 = 1.4 Hz), 2.33 (s, 3H), 2.34 (s, 3H), 6.49 (dd, 1H, J_1 = 15.6 Hz, J_2 = 1.4 Hz), 6.73 (qd, 1H, J_1 = 15.6 Hz, J_2 = 6.8 Hz), 7.10−7.16 (m, 2H), 7.17 (s, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 17.3, 18.7, 19.8, 127.6, 130.1, 130.2, 131.3, 132.6, 133.8, 138.1, 144.9, 194.9. MS (EI, 70 eV): m/z = 174, 159, 141, 131, 115, 15, 91, 79, 69, 41.

1-(2,5-Dimethylphenyl)-2-phenylprop-2-en-1-one (4c). Piperidine (0.13 mL, 1.3 mmol), acetic acid (0.12 mL, 2.1 mmol), and aq formaldehyde (37% solution, 4 mL, 50 mmol) were successively added to a magnetically stirred solution of **3c** (2.92 g, 13.0 mmol) in methanol (50 mL), and the resulting mixture was refluxed for 4 h and concentrated under reduced pressure. Water (50 mL) was added to the residue, and the mixture was extracted with CH_2Cl_2 (3 × 30 mL). Combined organic extracts were washed with water (2 × 50 mL) and brine (30 mL) and dried with $MgSO_4$, and solvent was evaporated under reduced pressure. The crude product was purified by flash column chromatography (silica, petroleum ether/ethyl acetate, 8:1) to give the title product. Yield: 97%; white crystals, mp 178.3−181.0 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.33 (s, 3H), 2.42 (s, 3H), 5.75 (s, 1H), 6.17 (s, 1H), 7.14 (d, 1H, J = 7.8 Hz), 7.19 (dd, 1H, J_1 = 7.8 Hz, J_2 = 1.3 Hz), 7.29 (d, 1H, J = 1.3 Hz), 7.38 (m, 3H), 7.47 (dd, 1H, J_1 = 7.9 Hz, J_2 = 1.7 Hz). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 19.9, 21.0, 120.7, 128.1, 128.4, 128.5, 129.9, 131.2, 131.6, 134.4, 135.0, 137.0, 138.7, 149.8, 199.9. MS (EI, 70 eV): m/z = 236, 159, 145, 133, 105, 77, 63, 51.

1-(2,5-Dimethylphenyl)-2-methylprop-2-en-1-one (4d). Acetic acid (10 mL) was added to a magnetically stirred suspension of

3d (1.62 g, 10 mmol) and aq formaldehyde (37% solution, 2.4 mL, 30 mmol). A catalytic amount (few drops) of morpholine was then added, and the resulting mixture was refluxed for 5 days. The reaction mixture was cooled to 20 °C, neutralized with aq NaOH (20%), and extracted with CH_2Cl_2 (3 × 50 mL). Combined organic extracts were washed with brine (50 mL) and dried with $MgSO_4$, and solvent was evaporated under reduced pressure. The flash column chromatography of the resulting mixture (silica, petroleum ether/ethyl acetate, 8:1) gave the product. Yield: 96%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 1.99 (s, 3H), 2.19 (s, 3H), 2.25 (s, 3H), 5.53 (s, 1H), 5.89 (s, 1H), 6.99 (s, 1H), 7.02 (d, 1H, J = 7.9 Hz), 7.06 (d, 1H, J = 7.9 Hz). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 17.0, 19.0, 20.6, 128.1, 129.5, 130.3, 130.5, 132.6, 134.3, 138.9, 145.0, 200.5. MS (EI, 70 eV): m/z = 174, 159, 145, 133, 115, 105, 91, 77, 65, 51, 41.

(*E*)-1-(4,5-Dimethoxy-2-methylphenyl)-3-phenylprop-2-en-1-one (4e). Prepared as **4a** from **3e** (2.62 g, 13.5 mmol). Yield: 72%; yellow solid; mp 107.1−109.8 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.45 (s, 3H), 3.89 (s, 3H), 3.93 (s, 3H), 6.75 (s, 1H), 7.10 (s, 1H), 7.17 (d, 1H, J = 15.1 Hz), 7.39−7.40 (m, 3H), 7.53 (d, 1H, J = 15.1 Hz), 7.56−7.59 (m, 2H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 20.6, 56.1, 56.4, 112.4, 114.4, 126.7, 128.5, 129.1, 130.6, 131.3, 131.6, 135.0, 144.9, 146.7, 151.1, 194.7. MS (EI, 70 eV): m/z = 282, 267, 251, 205, 191, 179, 165, 151, 131, 121, 103, 91, 77, 65, 51.

(*E*)-3-Phenyl-1-*o*-tolylprop-2-en-1-one (4h). Prepared as **4a** from *o*-methylacetophenone (1.81 g, 13.5 mmol). Yield: 88%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.49 (s, 3H), 7.17 (d, J = 16.0 Hz, 1H), 7.30−7.33 (m, 2H), 7.39−7.43 (m, 4H), 7.57−7.60 (m, 3H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 20.3, 125.6, 126.9, 128.2, 128.5, 129.1, 130.6, 130.7, 131.4, 134.8, 137.1, 139.2, 145.9, 196.5. MS (EI, 70 eV): m/z = 222, 178, 145, 131, 103, 91, 77, 65, 51.

General Procedure for the Synthesis of Epoxides 1a−e,h. H_2O_2 (30%, 2.9 mL, 28.9 mmol) was added dropwise to a stirred solution of an enone (**4a−e**,**h**; 11 mmol) in methanol (60 mL) cooled to 0 °C. Then a cooled solution (0 °C) of KOH (0.32 g, 5.7 mmol) in methanol (20 mL) was added, and the mixture was stirred at 0 °C for 2 h. The reaction progress was monitored by TLC. After completion, the reaction was quenched with water (100 mL) and extracted with CH_2Cl_2 (3 × 30 mL). The organic extracts were washed with brine (50 mL) and dried with $MgSO_4$, and the solvents were evaporated under reduced pressure. The crude product mixture was separated using flash column chromatography (silica, petroleum ether/ethyl acetate, 20:1 to 10:1) to give the title product.

(2,5-Dimethylphenyl)(3-phenyloxiran-2-yl)methanone (1a). Prepared from **4a** (2.60 g, 11 mmol). Yield: 94%; white crystals, mp 67.1−69.2 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.34 (s, 3H), 2.49 (s, 3H), 4.05 (d, 1H, J = 1.8 Hz), 4.10 (d, 1H, J = 1.8 Hz), 7.17 (d, 1H, J = 7.8 Hz), 7.24 (d, 1H, J = 7.8 Hz), 7.36−7.42 (m, 5H), 7.48 (s, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 20.6, 21.0, 59.6, 62.4, 126.0, 128.9, 129.0, 129.1, 129.5, 132.1, 133.1, 135.6, 135.7, 135.7, 197.0. MS (EI, 70 eV): m/z = 252, 237, 222, 207, 178, 148, 133, 119, 105, 91, 77, 51, 44. UV−vis (acetonitrile): ε_{313} = 1040 dm^3 mol^{-1} cm^{-1}, ε_{254} = 10 780 dm^3 mol^{-1} cm^{-1}. HRMS (EI$^+$): calcd for $C_{17}H_{17}O_2$ [M + H$^+$] 253.1229, found 253.1222.

(2,5-Dimethylphenyl)(3-methyloxiran-2-yl)methanone (1b). Prepared from **4b**. Yield: 80%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 1.47 (d, 3H, J = 5.1 Hz), 2.36 (s, 3H), 2.43 (s, 3H), 3.15 (dq, 1H, J_1 = 5.1 Hz, J_2 = 1.9 Hz), 3.74 (d, 1H, J = 1.9 Hz), 7.13 (d, 1H, J = 7.8 Hz), 7.21 (d, 1H, J = 7.8 Hz), 7.44 (s, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 17.5, 20.2, 20.9, 55.8, 59.7, 129.1, 131.7, 132.7, 135.2, 135.3, 135.8, 198.8. MS (EI, 70 eV): m/z = 175, 133, 117, 115, 105, 103, 79, 77, 58, 43. UV−vis (acetonitrile): ε_{313} = 775 dm^3 mol^{-1} cm^{-1}, ε_{254} = 8820 dm^3 mol^{-1} cm^{-1}. HRMS (EI$^+$): calcd for $C_{12}H_{15}O_2$ [M + H$^+$] 191.1072, found 191.1060.

(2,5-Dimethylphenyl)(2-phenyloxiran-2-yl)methanone (1c). Prepared from **4c**. Yield: 94%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.29 (s, 3H), 2.48 (s, 3H), 3.07 (d, 1H, J = 5.6 Hz), 3.30 (d, 1H, J = 5.6 Hz), 7.11 (d, 1H, J = 7.8 Hz), 7.17 (d, 1H, J = 7.8 Hz), 7.30−7.41 (m, 3H), 7.48−7.56 (m, 3H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 20.8, 21.1, 54.9, 63.6, 126.3, 128.3, 128.8, 131.0, 131.7, 132.8, 134.7, 135.1, 135.8, 136.4, 199.5. MS (EI, 70 eV: m/z = 252, 237, 193, 178, 133, 119, 105, 91, 77, 65. UV−vis (acetonitrile): ε_{313} = 730 dm^3 mol^{-1} cm^{-1}, ε_{254} = 7160 dm^3 mol^{-1} cm^{-1}. HRMS (EI$^+$): calcd for $C_{17}H_{17}O_2$ [M + H$^+$] 253.1229, found 253.1223.

(2,5-Dimethylphenyl)(2-methyloxiran-2-yl)methanone (1d). Prepared from **4d**. Yield: 80%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 1.66 (s, 3H), 2.32 (s, 6H), 2.80 (d, 1H, J = 5.3 Hz), 2.86 (d, 1H, J = 5.3 Hz), 7.08 (d, 1H, J = 7.8 Hz), 7.14 (dd, 1H, J_1 = 7.8 Hz, J_2 = 1.8 Hz), 7.23 (d, 1H, J = 1.8 Hz). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 17.7, 19.6, 21.0, 52.4, 59.9, 128.3, 130.9, 131.6, 134.1, 134.8, 135.7, 204.5. MS (EI, 70 eV): m/z = 190, 174, 159, 145, 133, 105, 91, 77, 65, 51, 41. UV−vis (acetonitrile): ε_{313} = 410 dm^3 mol^{-1} cm^{-1}, ε_{254} = 6120 dm^3 mol^{-1} cm^{-1}. HRMS (EI$^+$): calcd for $C_{12}H_{15}O_2$ [M + H$^+$] 191.1072, found 191.1067.

(4,5-Dimethoxy-2-methylphenyl)(3-phenyloxiran-2-yl)methanone (1e). Prepared from **4e**. Yield: 77%; white crystals, mp 136.3−137.7 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.51 (s, 3H), 3.80 (s, 3H), 3.91 (s, 3H), 4.05 (1H, J = 1.9 Hz), 4.06 (1H, J = 1.9 Hz), 6.73 (s, 1H), 7.27 (s, 1H), 7.33−7.41 (m, 5H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 21.3, 56.1, 56.3, 59.3, 62.7, 112.6, 114.7, 125.8, 127.54, 128.9, 129.1, 134.1, 135.8, 146.7, 152.4, 194.6. MS (EI, 70 eV): m/z = 282, 269, 191, 179, 152, 136, 121, 105, 91, 77, 65, 51. HRMS (EI$^+$): calcd for $C_{18}H_{19}O_4$ [M + H$^+$] 299.1283, found 299.1278.

(3-Phenyloxiran-2-yl)(*o*-tolyl)methanone (1h). Prepared from **4h**. Yield: 94%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.57 (s, 3H), 4.06 (d, 1H, J = 1.7 Hz), 4.13 (d, 1H, J = 1.7 Hz), 7.29−7.32 (m, 2H), 7.37−7.44 (m, 6H), 7.71 (d, 1H, J = 7.8 Hz). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 21.1, 59.6, 62.5, 126.0, 128.9, 129.1, 129.2, 132.2, 132.4, 135.6, 139.0, 196.7. MS (EI, 70 eV): m/z = 238, 119, 91, 77, 65, 51.

General Procedure for Irradiation of 1a−e; Preparation of 5a−d, 6b,d,e and 7b,d. A degassed (N_2) solution of the corresponding epoxide (**1a−e**, 5 × 10^{-3} M) in acetonitrile (200 mL) was irradiated with a 125- or 400-W Hg medium pressure UV lamp through a Pyrex filter (λ < 290 nm) until ∼95% conversion (HPLC) was reached (or ∼41% in the case of the epoxide **1c**). The solvent was removed under reduced pressure at the temperature below 40 °C to prevent a retro-aldol reaction. The resulting mixture was separated by flash column chromatography (silica, petroleum ether/ethyl acetate, 20:1 to 5:1) to give the title photoproducts.

2-(Hydroxy(phenyl)methyl)-6-methyl-2,3-dihydro-1*H*-inden-1-one (5a). Obtained from **1a**. Yield: 67%; colorless oil; two diastereomers (a ∼1:1 ratio). ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.41 (s, 3H), 2.43 (s, 3H), 2.65 (dd, J_1 = 17.4 Hz, J_2 = 4.4 Hz, 1H), 2.84−2.94 (m, 2H), 3.03−3.10 (m, 2H), 3.22 (dd, J_1 = 16.8 Hz, J_2 = 4.4 Hz, 1H), 4.80 (d, J = 9.7 Hz, 1H), 4.92 (s, broad), 5.59 (dd, J_1 = 3.1 Hz, J_2 = 3.1 Hz, 1H), 7.26−7.46 (m, 14H), 7.60 (s, 1H), 7.61 (s, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 21.3, 21.3, 26.6, 29.8, 53.7, 55.3, 72.4, 76.1, 124.0, 124.3, 125.8, 126.4, 126.5, 127.3, 127.6, 128.5, 128.7, 128.8, 136.5, 136.7, 137.0, 137.5, 137.6, 138.0, 141.7, 142.8, 151.6, 152.3, 207.5, 210.0. MS (EI, 70 eV): m/z = 252, 234, 146, 132, 117, 104, 91, 77, 65, 51, 32. UV−vis (acetonitrile): ε_{313} = 2520 dm^3 mol^{-1} cm^{-1}, ε_{254} = 9390 dm^3 mol^{-1} cm^{-1}. HRMS (EI$^+$): calcd for $C_{17}H_{17}O_2$ [M + H$^+$] 253.1229, found 253.1221.

2-(1-Hydroxyethyl)-6-methyl-2,3-dihydro-1*H*-inden-1-one (5b). Obtained from **1b**. Yield: 64%; colorless oil; two diastereomers (a ∼1:1 ratio). Diastereomer A: ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 1.29 (d, 3H, J = 6.2 Hz), 2.41 (s, 3H), 2.65 (ddd, 1H,

J_1 = 9.0 Hz, J_2 = 8.0 Hz, J_3 = 4.5 Hz) 2.75 (dd, 1H, J_1 = 17.0 Hz, J_2 = 4.5 Hz), 3.24 (dd, 1H, J_1 = 17.0 Hz, J_2 = 8.0 Hz), 3.98 (dq, 1H, J_1 = 9.0 Hz, J_2 = 6.2 Hz), 4.36 (broad, 1H), 7.36 (d, 1H, J = 7.9 Hz), 7.44 (d, 1H, J = 7.9 Hz), 7.56 (s, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 21.1, 21.6, 29.5, 53.8, 69.2, 124.0, 126.2, 136.7, 136.9, 137.8, 151.3, 210.0. Diastereomer B: ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 1.28 (d, 3H, J = 6.4 Hz), 2.40 (s, 3H), 2.80 (ddd, 1H, J_1 = 8.0 Hz, J_2 = 4.5 Hz, J_3 = 3.6 Hz) 3.07 (dd, 1H, J_1 = 17.0 Hz, J_2 = 4.5 Hz), 3.17 (dd, 1H, J_1 = 17.0 Hz, J_2 = 8.0 Hz), 4.46 (dq, 1H, J_1 = 6.4 Hz, J_2 = 3.6 Hz), 7.36 (d, 1H, J = 7.9 Hz), 7.44 (d, 1H, J = 7.9 Hz), 7.56 (s, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 20.8, 21.1, 27.3, 54.3, 67.4, 123.7, 126.4, 136.3, 136.6, 137.4, 152.0, 208.4. MS (EI, 70 eV, m/z): 190, 175, 133, 129, 105, 91, 77, 69, 43. UV−vis (acetonitrile): ε_{313} = 1340 dm^3 mol^{-1} cm^{-1}, ε_{254} = 8030 dm^3 mol^{-1} cm^{-1}. HRMS (EI$^+$): calcd for $C_{12}H_{15}O_2$ [M + H$^+$] 191.1072, found 191.1056.

2-(Hydroxymethyl)-6-methyl-2-phenyl-2,3-dihydro-1*H*-inden-1-one (5c). Obtained from **1c**. Yield: 82% (at a 41% conversion of **1c**); colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.43 (s, 3H), 3.97 (d, 1H, J = 17.0 Hz), 4.13 (d, 1H, J = 17.0 Hz), 4.15 (d, 1H, J = 10.9 Hz), 4.27 (d, 1H, J = 10.9 Hz), 7.27−7.46(m, 7H), 7.63 (s, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 21.2, 38.8, 58.6, 68.0, 124.5, 126.2, 127.0, 127.3, 128.9, 136.6, 136.9, 137.9, 140.4, 150.7, 208.3. MS (EI, 70 eV): m/z = 238, 119, 91, 77, 65. UV−vis (acetonitrile): ε_{313} = 2270 dm^3 mol^{-1} cm^{-1}, ε_{254} = 10 140 dm^3 mol^{-1} cm^{-1}. HRMS (EI$^+$): calcd for $C_{17}H_{17}O_2$ [M + H$^+$] 253.1229, found 253.1223.

2-(Hydroxymethyl)-2,6-dimethyl-2,3-dihydro-1*H*-inden-1-one (5d). Obtained from **1d**. Yield: 66%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 1.24 (s, 3H), 2.39 (s, 3H), 2.84 (d, 1H, J = 17.0 Hz), 3.18 (d, 1H, J = 17.0 Hz), 3.62 (d, 1H, J = 10.7 Hz), 3.81 (d, 1H, J = 10.7 Hz), 7.34 (d, 1H, J = 7.8 Hz), 7.43 (d, 1H, J = 7.8 Hz), 7.53 (s, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 14.2, 20.7, 37.7, 51.1, 67.9, 124.1, 126.3, 136.0, 136.5, 137.4, 150.6, 211.1. MS (EI, 70 eV): m/z = 190, 172, 159, 145, 132, 129, 115, 105, 91, 77, 51, 32. UV−vis (acetonitrile): ε_{313} = 880 dm^3 mol^{-1} cm^{-1}, ε_{254} = 6560 dm^3 mol^{-1} cm^{-1}. HRMS (EI$^+$): calcd for $C_{12}H_{15}O_2$ [M + H$^+$] 191.1072, found 191.1067.

1-(2,5-Dimethylphenyl)-3-hydroxybut-2-en-1-one (6b). Obtained from **1b**. Yield: 7%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.17 (s, 3H), 2.34 (s, 3H), 2.45 (s, 3H), 5.84 (s, 1H), 7.11 (d, 1H, J = 7.8 Hz), 7.15 (d, 1H, J = 7.8 Hz), 7.28 (s, 1H), 15.96 (broad, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 20.3, 21.0, 25.8, 101.0, 129.0, 131.5, 131.6, 134.1, 135.5, 136.0, 188.4, 193.2. MS (EI, 70 eV): m/z = 190, 172, 132, 129, 115, 104, 77, 43, 32. HRMS (EI$^+$): calcd for $C_{12}H_{15}O_2$ [M + H$^+$] 191.1072, found 191.1059.

1-(2,5-Dimethylphenyl)-3-hydroxy-2-methylprop-2-en-1-one (6d). Obtained from **1d**. Yield: 7%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 1.68 (s, 3H), 2.26 (s, 3H), 2.33 (s, 3H), 6.99 (s, 1H), 7.13 (s, 2H), 8.54 (d, 1H, J = 4.8 Hz), 14.94 (d, 1H, J = 4.8 Hz). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 13.2, 18.8, 21.1, 127.3, 130.5, 130.7, 135.4, 136.3, 184.4, 208.1. MS (EI, 70 eV): m/z = 190, 172, 159, 145, 132, 129, 115, 104, 91, 77, 32. HRMS (EI$^+$): calcd for $C_{12}H_{15}O_2$ [M + H$^+$] 191.1072, found 191.1067.

1-(4,5-Dimethoxy-2-methylphenyl)-3-hydroxy-3-phenylprop-2-en-1-one (6e). Obtained from **1e**. Yield: 70%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 2.54 (s, 3H), 3.91 (s, 3H), 3.92 (s, 3H), 6.51 (s, 1H), 6.74 (s, 1H), 7.15 (s,1H), 7.44−7.54 (m, 3H), 7.95 (m, 2H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 21.0, 56.2, 56.4, 97.2, 112.0, 114.5, 127.2, 128.9, 131.3, 132.5, 135.7, 147.1, 151.3, 184.3, 190.0 (see an HMBC spectrum in the Supporting Information, S30). MS (EI, 70 eV): m/z = 298, 283, 267, 221, 192, 179, 150, 136, 121, 105, 91, 77, 69, 51. HRMS (EI$^+$): calcd for $C_{18}H_{19}O_4$ [M + H$^+$] 299.1283, found 299.1278.

3,7-Dimethyl-3,4-dihydrobenzo[*c*]oxepin-5(1*H*)-one (7b). Obtained from **1b**. Yield: 12%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 1.33 (d, 3H, J = 6.3 Hz), 2.38 (s, 3H), 2.85 (dd, 1H, J_1 = 13.5 Hz, J_2 = 5.8 Hz), 3.16 (dd, 1H, J_1 = 13.5 Hz, J_2 = 5.5 Hz), 4.24 (tq, 1H, J_1 = 6.3 Hz, J_2 = 6.1 Hz,), 4.84 (d, 1H, J = 15.3 Hz), 4.94 (d, 1H, J = 15.3 Hz), 7.12 (d, 1H, J = 7.7 Hz), 7.26 (d, 1H, J = 7.7 Hz), 7.66 (s, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 21.1, 21.3, 50.0, 69.4, 71.4, 127.8, 129.2, 132.9, 137.5, 137.9, 139.6, 200.5. MS (EI, 30 eV): m/z = 190, 149, 119, 103, 91, 77, 65, 51, 39. HRMS (EI$^+$): calcd for $C_{12}H_{15}O_2$ [M + H$^+$] 191.1072, found 191.1062.

4,7-Dimethyl-3,4-dihydrobenzo[*c*]oxepin-5(1*H*)-one (7d). Obtained from **1d**.Yield: 15%; colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 1.14 (d, 3H, J=6.7 Hz), 2.37 (s, 3H), 3.26−3.38 (m, 1H), 3.65 (dd, 1H, J_1 = 10.7 Hz, J_2 = 10.7 Hz), 4.00 (dd, 1H, J_1 = 10.7 Hz, J_2 = 6.8 Hz), 4.83 (d, 1H, J = 15.2 Hz), 4.94 (d, 1H, J = 15.2 Hz), 7.10 (d, 1H, J = 7.7 Hz), 7.24 (d, 1H, J = 7.7 Hz), 7.58 (s, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 11.6, 21.1, 46.6, 71.9, 72.8, 127.4, 129.3, 132.3, 137.7, 138.5, 138.7, 204.1. MS (EI, 30 eV, m/z): 190, 149, 119, 103, 91, 77, 65, 51, 39. HRMS (EI$^+$): calcd for $C_{12}H_{15}O_2$ [M + H$^+$] 191.1072, found 191.1053.

(*E*)-2-Ethylidene-6-methyl-2,3-dihydro-1*H*-inden-1-one (8). KOH (0.10 g, 1.7 mmol) was added to a stirred solution of **2b** (50 mg, 0.26 mmol) in methanol (30 mL). The reaction mixture was heated to 40 °C in the period of 20 min and then extracted with CH_2Cl_2 (3 × 10 mL). The combined organic layers were washed with brine (30 mL) and dried with $MgSO_4$, and the solvent was evaporated under reduced pressure. The crude product was purified by flash chromatography (silica, petroleum ether/ethyl acetate, 10:1) to give **8**. Yield: 97%; colorless oil. GC showed a mixture of the (*E*)- and (*Z*)-isomers in a 94:6 ratio. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 1.97 (dt, 3H, J_1 = 7.2 Hz, J_2 = 2.1 Hz), 2.43 (s, 3H), 3.62 (broad s, 2H), 6.94 (tq, 1H, J_1 = 7.1 Hz, J_2 = 2.1 Hz), 7.38−7.43 (m, 2H), 7.67 (s, 1H). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ (ppm) 15.54, 21.38, 29.70, 124.6, 126.2, 132.9, 135.8, 137.6, 138.3, 139.3, 146.8, 193.5. MS (EI, 70 eV): m/z = 172, 157, 143, 129, 115, 102, 77, 63, 51. HRMS (EI$^+$): calcd for $C_{12}H_{13}O$ [M + H$^+$] 173.0966, found 173.0962.

Irradiation Experiment in an NMR Cuvette. D_2O (25 μL) was added to a solution of **1h** (20 mg) in acetone-d_6 (500 μL) in an NMR cuvette. The resulting solution was purged with argon for 10 min. ^{1}H NMR was measured in 15-min intervals of irradiation by a 125-W medium pressure Hg UV lamp through a Pyrex filter (λ < 290 nm).

Quantum Yield Measurements. The quantum yield measurements were performed on an optical bench consisting of high pressure 350- or 450-W UV lamps, a 1/8 m monochromator with 200−1600 nm grating, set to 313 nm, and a 1.0-cm matched quartz cell containing a solution degassed by purging with argon for 10 min. The sample temperature was maintained using a Peltier thermo block set to 20 °C. The light intensity was monitored by a Si photodiode detector (UV enhanced) with a multifunction optical power meter. The concentration of all sample solutions was in the interval of 1×10^{-3} and 5×10^{-4} M, containing hexadecane (10^{-3} M; GC) or acetone (10^{-2} M; HPLC) as internal standards. Valerophenone was used as an actinometer in all cases.[42] The reaction conversions were always kept below 10% to avoid the interference of photoproducts. The relative standard deviations of the mean for multiple (at least five) samples were found below 10% in all analyses.

Steady-State Quenching Experiments. Stern−Volmer analysis was performed with naphthalene as a triplet quencher in a merry-go-round apparatus (see also the Supporting Information, S41). Samples in Pyrex tubes (13 × 120 mm) were degassed by purging with argon for 10 min. The concentration of all sample solutions was approximately 5×10^{-3} M, and they contained hexadecane (10^{-3} M) as an internal standard for GC measurements. Three degassed tubes for a given naphthalene concentration were irradiated using a medium pressure

400-W Hg lamp; the $\lambda = 366$ nm band was isolated by an optical filter in order to avoid the absorption by naphthalene.

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Supporting Information Available: ^{1}H and ^{13}C NMR spectra of new compounds; ^{1}H−^{1}H COSY and ^{1}H−^{13}C HMBC NMR correlations; Stern−Volmer analysis; kinetic traces from laser flash photolysis experiments; UV−vis spectra of **1a**−**d** and **5a**−**d**; total Gibbs free energies (with scaled thermal corrections) of calculated species discussed in the article; TD-DFT electronic transitions; Cartesian coordinates of optimized structures with the corresponding transition states. This material is available free of charge via the Internet at http://pubs.acs.org.