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Stereoselective Photocyclization to 2-Aminocyclopropanols by Photolysis of β-Aminoketones and Oxidative Ring Opening to Enaminones

Wilfried Weigel,* Sabine Schiller and Hans-Georg Henning

Department of Chemistry, Humboldt-University of Berlin, Hessische Str. 1-2, D-10115 Berlin, Germany

Abstract: Irradiation of β-aminopropiophenones **1** leads to the formation of 2-aminocyclopropanols **2** which can undergo oxidative ring opening to give enaminones **3**. The regioselectivity of cyclopropanol formation of the α-benzyl substituted **1** is determined by the preferred charge transfer interaction between the photoexcited benzoyl chromophore and the amino group. The photocyclizations of the α- or β-substituted **1** proceed stereoselectively. No photoracemization of the pure enantiomers of **1m**, independent of the solvent polarity was observed. Aryl or alkyl substituents at the C(3)- or C(2)-ring atom stabilize the cyclopropanol derivatives. The formation of **3** indicates regioselective C(1)-C(2) ring opening of **2** probably by localization of the excitation energy. © 1997 Elsevier Science Ltd.

INTRODUCTION

Intramolecular hydrogen abstraction by photoexcited benzoyl groups of aryl alkyl ketones has attracted much interest from the mechanistic and synthetic point of view.[1] The hydrogen abstraction leads to the formation of hydroxybiradicals that can cyclize to yield cyclic hydroxy compounds. In contrast to the well documented photocyclization to cyclobutanol or cyclopentanol derivatives only few examples of cyclopropanol formation via β-hydrogen abstraction have been reported.[2-4] Electron donors, such as an amine or aromatic moiety at the alkyl chain of photoexcited aryl alkyl ketones can lead to inter- and intramolecular charge transfer (CT) interactions which can compete or contribute to hydrogen transfer.[5-9]

Irradiation of β-aminopropiophenones in presence of oxygen yields α,β-unsaturated ketones. Roth reported the photodehydrogenation of β-(*N*-alkylamino)propiophenones leading to iminoketones. Cyclic hemiaminals formed by 1,6-hydrogen abstraction were proposed as intermediates which undergo oxidative ring opening.[10] Recently we reported the formation of enaminone derivatives by irradiation of β-(*N,N*-dialkylamino)propiophenones in presence of oxygen and the role of 2-aminocyclopropanols as intermediates.[4] The reactivity of cyclopropane derivatives to oxygen has been the subject of numerous investigations.[11,12]

We report here the detailed results of our investigation of the photocyclization of β-(*N,N*-dialkylamino)propiophenone derivatives **1** and subsequent oxidative ring opening of the 2-aminocyclopropanols **2** to enaminones **3**. The stereoselectivity of the cyclopropanol formation is found to be highly dependent upon α- or β-substituents on the alkyl chain of the β-aminoketones. The influence of ring substituents on the regioselectivity of ring opening of the aminocylopropanol derivatives will be discussed.

RESULTS AND DISCUSSION

Photocyclization to 2-Aminocyclopropanols. Irradiation > 300 nm leads to a photoexcited triplet benzoyl group in **1a-s**. The absorption spectra during the photolysis of **1a-s** in methanol under argon show a decrease of the absorption intensity by the benzoyl chromophore and the formation of a new blue shifted absorption band near 230 nm, Figure 1. 2-Aminocyclopropanols **2** were isolated from the photolysates of the α- or β-substituted aminoketones **1m-s**, as previously reported for **1m** and **1o-q**,[2,4] Table 1.

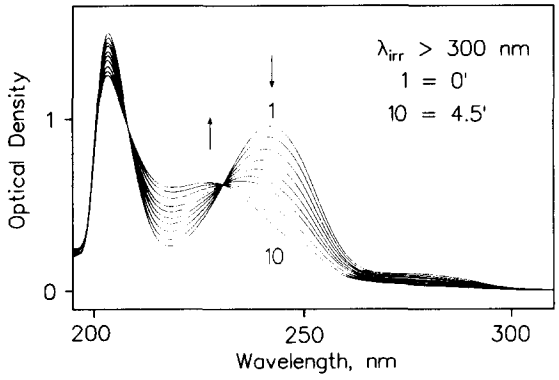
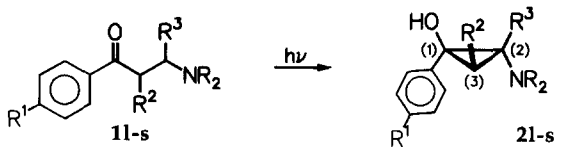


Figure 1. Absorption spectra during the photolysis of **1o** in methanol.

The relative configurations of **2m** and **2q** were determined by X-ray structural analysis and reported earlier.[4] The hydroxy and the C(3)-substituent are arranged in *trans*-configuration relative to the morpholino group. Unfortunately attempts to isolate **2a-l** by chromatography failed due to their sensitivity to H^+ and OH^- ions.[13] They are less stable than **2m-s** because of the lack of additional ring substituents at the C(2)- or C(3)-ring carbon which increase the stability of the cyclopropanols, except **2l**. However, the new blue shifted absorption maximum near 230 nm by the photolysis of **1a-l** clearly indicates that a chromophore similar to **2m-s** is formed, Table 1. The β-aminoketones also underwent photoreaction when irradiated as KBr pellets. The decrease in the C=O absorption signal along with simultaneous appearance of a new O-H absorption band (**1d**: 3406, **1e**: 3407, **1g**: = 3397, **1i**: 3415 cm^{-1}) was observed. Thus it is assumed that 2-aminocyclopropanols are also formed by photolysis of α,β-unsubstituted **1a-l**.

Regioselectivity of Photocylization. The photocyclization of **1s** and **1p** could involve hydrogen abstraction from two different β-methylene groups. As expected geometrical requirements for hydrogen transfer[14] exclude the involvement of the two remote β-hydrogens on the naphthalenone ring of **1s** (fixed distance to carbonyl oxygen ~4 Å). The similar chemical shifts of the phenyl methylene group in **1p** (36.9 ppm) and **2p** (32.5 ppm) assigned from ^{13}C NMR/APT spectra (amino methylene groups appear at 45-55 ppm) show that the photocyclization involves the β-amino methylene hydrogens. This conclusion is supported by the chemical shift of 58.3 ppm for the C(2)-ring carbon of **2p** similar to the values detected for **2m-o,q** (58.0 - 58.9 ppm). The regioselectivity of cyclopropanol formation can be explained by the preferred CT interaction

between the amino group, as the stronger donor, and the triplet benzoyl group (cp. $E_{1/2}^{ox}$ of the model donors: triethylamine = 0.76 V[15] and toluene = 1.98 V,[16] SCE, CH_3CN).



Scheme 1.

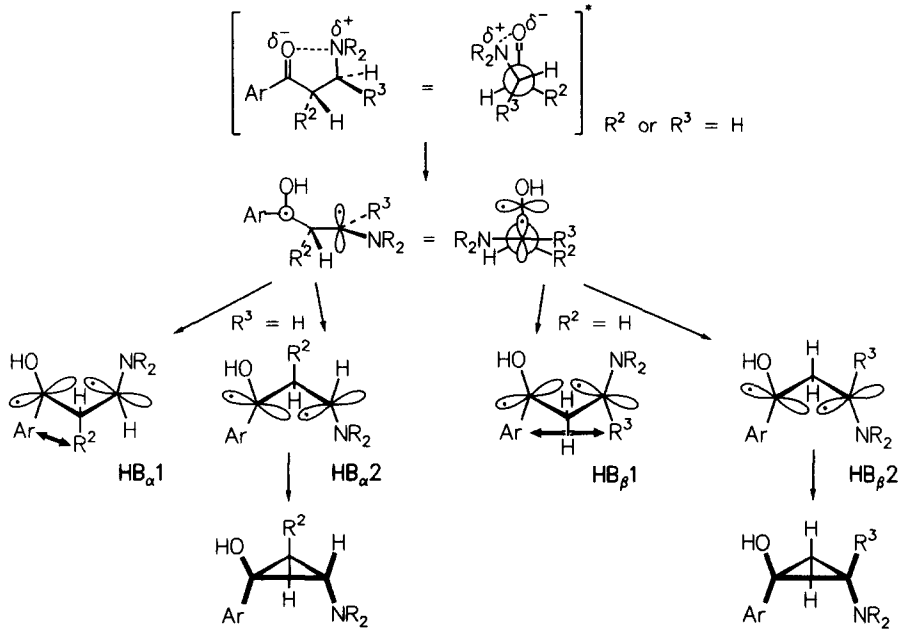
Table 1. Yields and Absorption Maxima of the 2-Aminocyclopropanols **2** from > 300 nm Irradiation of **1** in Diethyl Ether and for the Enaminones **3** (R^2 = H) from Irradiation > 300 nm of **1** in Methanol (**1a** and **1e-s**: NR_2 = morpholino, **1b** and **1d**: NR_2 = piperidino, **1c**: NR_2 = dimethylamino).

1	R^1	R^2	R^3	Yield of **2**, %	λ_{max}, of **2**, nm[a]	Yield of **3**, %[b]	λ_{max}, of **3**, nm[a]
a	H	H	H	-	227	46[c]	346
b	H	H	H	-	228	38	346
c	H	H	H	-	227	59	345
d	NC	H	H	-	-	75	362
e	NC	H	H	-	-	60[c]	359
f	F	H	H	-	223	38[c]	343
g	Cl	H	H	-	228	42[c]	347
h	Br	H	H	-	233	20	348
i	MeO	H	H	-	227	22[c]	344
j	Ph	H	H	-	261[d]	16	353
k[e]	Me-CO-O	H	H	-	230	17	344
l	H	H	4-NC-C_6H_4	-	230	61	346
m	H	H	Ph	87[c]	224	52[c]	344
n	H	H	4-MeO-C_6H_4	70	230	18	348
o	H	Me	H	50	225	-	-
p	H	Ph-CH_2	H	75[c]	228	-	-
q	H	Ph	H	98[c]	233	-	-
r[f]	HO	Me	H	30	233	-	-
s[g]	H	[g]	H	72	231	-	-

[a] in methanol. [b] maximal yields during photolysis. [c] yields reported in ref. (4). [d] cp. biphenyl λ_{max} = 248 nm in ethanol [e] 1-aryl = 4-acetoxy-3,5-di-*tert*-butyl-phenyl. [f] 1-aryl = 3,5-di-*tert*-butyl-4-hydroxyphenyl. [g] **1s** = 2-(morpholino-methyl)-1,2,3,4-tetrahydro-1-naphthalinone.

Intramolecular CT and Stereoselectivity of Photocyclization. The photocyclization proceeds via formation of a 1,3-hydroxybiradical by 1,5-hydrogen transfer. The extent of CT between the photoexcited benzoyl and the β-amino group of **1** determines if the 1,3-hydroxybiradical will be formed by hydrogen atom transfer in a polarized triplet state or by proton transfer in a radical ion pair. The formation of a radical ion pair by intramolecular electron transfer has been reported for photoexcited β-dimethylaminopropiophenone (**1c**) in aqueous solvents.[17] Full electron transfer is less probable in nonpolar solvents. However, a ΔG value of -7 kcal/mol for the acetophenone ($E_{1/2}^{ox}$ = -2.14 V, E_T = 3.2 eV),[9] triethylamine ($E_{1/2}^{red}$ = 0.76 V)[15] system was estimated from the Rehm-Weller equation.[18] This value and the high efficiency of the photocyclizations of various β-dimethylaminopropiophenone derivatives ($\Phi \approx 0.4$[19]) strongly suggest the electron/proton transfer pathway.

The photocyclization of the racemic α- or β-substituted **1m-r** proceeds diastereoselectively (de > 90 %) independent of the solvent polarity (*n*-hexane, diethyl ether, 2-propanol). Irradiation of the enantiomerically pure **1q** and **1m** gave only one of the four possible stereoisomeric products.[4] No photoracemization was observed for the pure enantiomers of **1m** in *n*-hexane, diethyl ether or 2-propanol. Nonpolar solvents like *n*-hexane should promote back hydrogen transfer in comparison to Lewis base solvents which can stabilize the hydroxybiradical. It is assumed that the 1,3-hydroxybiradical collapses so rapidly to the cyclopropanol as to prevent 180° rotation of the C(1)-C(2)-C(3) bond or back hydrogen transfer.



Scheme 2. Influence of α- and β-substituents on the stereoselectivity of photocyclization of **1**.

In contrast to 4- or 5-membered ring systems the substituents on cyclopropane rings are arranged in an eclipsed conformation. Thus interaction between the C(1)-, C(2)- and C(3)-substituents in the 1,3-hydroxy-biradical should increase during the bond forming step leading to the cyclopropanol. Scheme 2 depicts the geometry of CT interaction in photoexcited **1**, the preferred hydroxybiradical geometry and the conceivable conformations of the biradical during the ring closure to **2**. A relative small change in the conformation of the CT state would allow proton transfer that should be highly regioselective in case of an α-substituent. Repulsive interaction between the C(1)-aryl and R^2 in $\mathbf{HB_\alpha 1}$ should favor ring closure of $\mathbf{HB_\alpha 2}$. The resulting cyclopropanol configuration corresponds with the X-ray structure of **2q**. It is interesting to note the similar effect of α-substituents on the stereochemistry of closure of 1,4-biradicals to cyclobutanols.[20] In the β-case only two of the possible four biradical conformations have to be considered due to the lack of photoracemization. The repulsive interactions during ring closure between the C(1)-phenyl and R^3 in $\mathbf{HB_\beta 1}$ presumably determine the stereoselectivity in cyclopropanol formation of the β-substituted **1**.

Formation of Enaminones by Photolysis of 1. The irradiation ($\lambda_{irr} > 300$ nm) of **1a-n** ($R^2 = H$) in methanol in presence of oxygen leads to a decrease in the intensity of the absorption by the benzoyl chromophore and a new, red shifted absorption band appears at 350 nm, Figure 2. β-Aminovinyl aryl ketones **3a-n** are formed as the main photoproducts, Scheme 3. In contrast to this the α-substituted **1** only give **2** as described before. Yields for the enaminones **3** and wavelengths of the characteristic 350 nm absorptions are reported in Table 1.

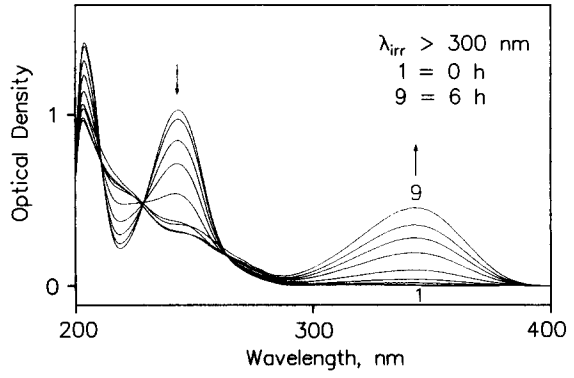
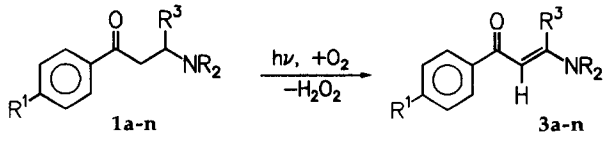


Figure 2. Absorption spectra during the photolysis of **1f** in methanol in presence of oxygen.



1a-n **3a-n**

Scheme 3.

HPLC analysis during the photolysis of **1a-n** indicated that an intermediate is formed in the reaction **1** → **3**, Figure 3. It was isolated in case of **1m** and **1n** and was identical to the cyclopropanols **2m** and **2n**, Table 1. The photolysis (λ_{irr} = 254 nm) of isolated **2m** in methanol gave the enaminone **3m** in a low yield of 15% that can be explained by the photofragmentation of **3m** itself. Irradiation > 300 nm of **2m** in methanol gave **3m** in 50% yield. In contrast to **2m** the direct irradiation of **2q** only gave traces of benzoic acid detected by HPLC.

As the photoreaction proceeds an increasing part of the irradiation light is absorbed by **3** due to the increasing intensity of the CT band at 350 nm. Thus long irradiation times, up to 60 h, were necessary to achieve high conversions of **1**. E,Z isomerization is one possible deactivation pathway of the photoexcited **3**,[21] whereas the yield of **3** decreases by secondary reactions, Figure 3. The corresponding substituted benzoic acids with yields of up to 45% were formed as minor products by photolysis of **1** and were identified by HPLC analysis with authentic reference compounds. Isolation and identification of other side or secondary products were complicated due to their small amounts. The reported yields of **3** are the maximum values which were observed during photolysis (consumption of **1** > 90%). The highest yield of **3c** after 60 min irradiation of **1c** was determined to be 56% in methanol, compared to 49% in isopropanol, 46% in acetonitrile and 34% in toluene.

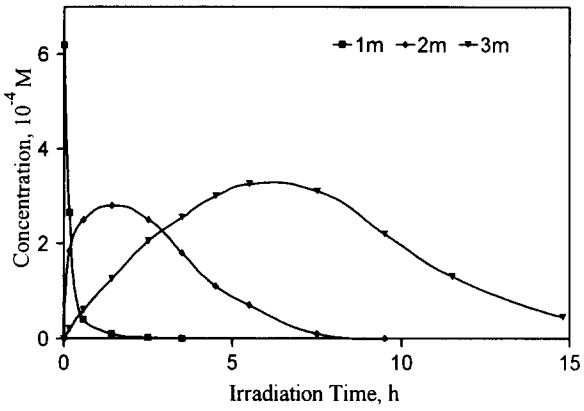
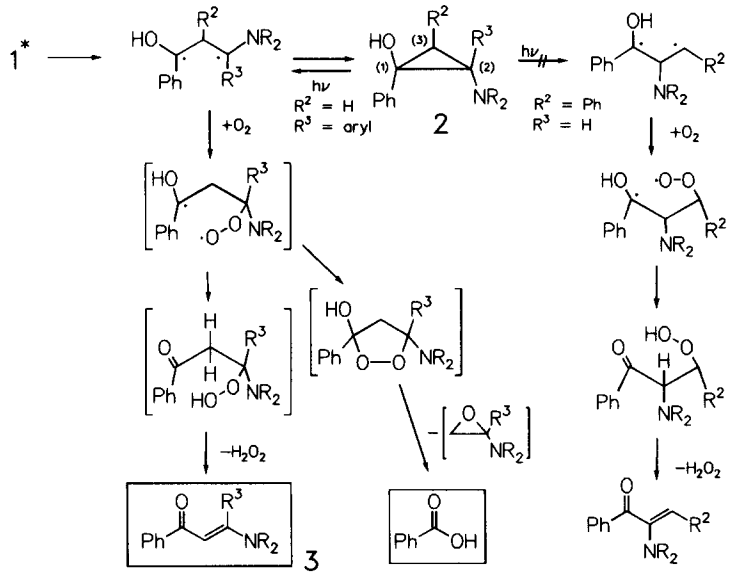


Figure 3. Concentration/time diagram during the photolysis of **1m** ($R^1 = R^2 = H$, $R^3 = Ph$) in methanol.

Regioselectivity of Ring Opening of 2. The cyclopropanols **2** are stabilized by ring substituents like alkyl groups by hyperconjugative interaction and aryl groups by overlap with their π-systems. The role of overlap control for the regioselectivity of ring cleavage was reported for the photochemical *cis-trans* isomerization of aryl cyclopropanes.[22] Formation of the enaminones **3** requires a C(1)-C(2) cleavage of **2**. It seems to be reasonable for the C(2)-aryl substituted **2l-n** that C(1)-C(2) ring opening can be explained by the localization of the excitation energy in the C(1)-C(2) bond by overlap with the π-orbitals of the two aryl groups at C(1) and C(2). Analogous consideration for the C(3)-phenyl substituted **2q** should lead to the C(1)-C(3) ring cleavage. Scheme 4 depicts the dependence of the regioselectivity of ring opening of **2** on the C(2)- or C(3)-position of the aryl substituent and the reaction of the formed hydroxybiradicals with oxygen to give an enaminone or α-aminochalcone. Figure 3 shows the reaction sequence **1m** → **2m** → **3m**. However, a portion of the 1,3-hydroxybiradicals formed by hydrogen transfer may undergo direct reaction with oxygen to give **3**.

A possible pathway for the formation of the benzoic acids as side products via dioxolane derivatives is also proposed. The question remains, why the C(3)-substituted **2o-s** do not undergo photooxidation. However, the C(3)-phenyl group in **2q** is arranged in an almost bisected conformation that stabilizes the cyclopropanol whereas the π-overlap in **2m** is reduced by an almost perpendicular conformation of the C(2)-phenyl group and

the cyclopropane ring due to the C(2)-NR_2 group.[4] It should be noted that the low energy of the donor acceptor substituted enes **3** should favour their formation over that of an assumed α-aminochalcone. Furthermore the amino and hydroxy group in **2** should lead to a lengthening of the C(1)-C(2) bond.[23] In fact the bond lengths determined from the X-ray structure of **2m** amount to 1.54 Å for the C(1)-C(2) bond, compared to 1.50 and 1.51 Å for the C(2)-C(3) and C(1)-C(3) bond, respectively.[4] A similar effect could explain why the cyclopropanol intermediates **2a-k** exclusively give **3** via oxidative C(1)-C(2) bond cleavage.



Scheme 4. Influence of C(2)- or C(3)-aryl substituents on the regioselectivity of ring opening of the 2-aminocyclopropanols.

In summary it can be stated that the primary reaction of photoexcited β-(*N*,*N*-dialkylamino)-propiophenones **1** is the cyclization to 2-aminocyclopropanols **2** even if enaminones **3** are the only photoproducts which can be isolated. Substituents at the α- or β-position of **1** determine the stereoselectivity of the photocyclization presumable due to repulsive interaction during the ring closure of the intermediate 1,3-hydroxybiradicals. The enaminones are formed by C(1)-C(2)-ring opening of the 2-aminocyclopropanols and subsequent reaction with oxygen. Their formation reflects the reactivity of **2** towards oxygen and in case of an aryl group at the C(2)-ring carbon the regioselectivity in ring opening probably due to the localization of the excitation energy.

EXPERIMENTAL SECTION

General. NMR spectra were recorded in $CDCl_3$ solutions using a Bruker AM 300 spectrometer with TMS as an internal standard. Mass spectra were determined with a Hewlett-Packard GCMS-5995A using an ionizing voltage of 70 V. IR spectra (KBr) were obtained using a Perkin-Elmer IR 881 spectrometer. Ultraviolet absorption spectra were recorded on a Kontron Uvicon 930 or Carl Zeiss Jena Specord UV/VIS. Melting points were determined with a Boetius hot stage apparatus and are uncorrected. Analytical HPLC was performed on a Kontron 322 system equipped with a two channel UV 430 detector. HPLC analyses were carried out using a Merck 250x4 mm Lichrospher RP 18 (5 μm) column and a mobile phase of methanol/water 10-40% in water. Semipreparative HPLC was done on a Knauer 250x20 mm Lichrosorb Si 60 (7 μm) column using dichloromethane/methanol as mobile phase. Racemic **1** were separated in the pure enantiomers by using a Daicel 250x4.6 mm Chiracel OD (10 μm) column and a mobile phase of n-hexane/2-propanol (95:5). Preparative column chromatography was performed on Merck Kieselgel 60 (40-63 or 63-200 μm) and size exclusion chromatography on Pharmacia Sephadex LH 20 using chloroform/methanol (2:1) as mobile phase.

Irradiations to record ultraviolet spectra during the photolysis were carried out using an optical bench (Narva 500 W highest pressure mercury lamp, cut off filter WG 6 $\lambda > 300$ nm, interference filter $\lambda \sim 254$ nm). Preparative irradiations were carried out in a photo reactor (Otto Fritz Gmbh, Hanau 500 W highest pressure mercury lamp, TQ 718). A pyrex inset was used to cut wavelength < 300 nm. Product yields of the photoreactions are based on HPLC integration. Calibration factors were determined independently under the same conditions for each particular analysis.

Materials. Methanol and diethyl ether for ultraviolet spectroscopy were Merck Uvasol spectroscopic grade and were used as received. Methanol (reagent grade material) for photopreparative irradiations was refluxed over magnesium and destilled for photochemical studies. Diethyl ether was dried over potassium hydroxide, destilled and stored over sodium metal. The *β*-aminoketones **1a-c** and **1o** were prepared as published.[24] The syntheses of the *β*-aminoketones **1d-n** and **1p-s** were modified by using the amine hydrochloride, *tert*-butanol/cyclohexane (v/v=3:1) as solvent and removing water by a water trap. The aminoketones **1f-l**,[24-27] **1q**[28] and **1s**[29] had the same properties as already reported.

1-(4-Cyano)phenyl-3-piperidinopropan-1-one (1d). mp 35-37°C; IR 2233, 1686 cm^{-1}; ^1H NMR 1.39 (m, 2H), 1.56 (m, 4H), 2.78 (t, 2H, J = 7.0 Hz), 3.23 (t, 2H, J = 7.0 Hz), 7.8 (d, 2H, J = 8.4 Hz), 8.05 (d, 2H, J = 8.4 Hz); MS, m/e 242 (M^+, 9%), 157 (14), 130 (3), 112 (5), 102 (30), 98 (100); UV $\lambda_{max.}$ (CH_3OH) 247 (ε = 18621), 326 nm (ε = 120).

1-(4-Cyano)phenyl-3- morpholino propan-1-one (1e). mp 76°C; IR 1680, 2240 cm^{-1}; ^1H NMR 2.50 (m, 4H), 2.85 (t, 2H, J = 7.1 Hz), 3.23 (t, 2H, J = 7.1 Hz), 3.70 (m, 4H), 7.80 (d, 2H, J = 8.5 Hz), 8.08 (d, 2H, J = 8.4 Hz); MS, m/e 244 (M^+, 3%), 158 (3), 130 (22), 114 (5), 102 (27), 100 (100); UV (CH_3OH) 248 (ε = 18197), 326 nm (ε = 102).

1-(4-Acetoxy-3,5-di-*tert*-butyl)phenyl-3-morpholinopropan-1-one (1k). mp 132°C; IR 1765, 1690 cm^{-1}; ^1H NMR 1.35 (s, 18H), 2.37 (s, 3H), 2.48 (m, 4H), 2.71 (m, 2H), 3.16 (m, 2H), 3.55 (m, 4H), 7.89 (s, 2H); MS, m/e 389 (M^+, 2%), 346 (4), 260 (2), 233 (3), 114 (7), 100 (100), 43 (36); UV (CH_3OH) 260 (ε = 12589), 320 nm (ε = 102).

2-Benzyl-3-morpholino-1-phenylpropan-1-one (1p). mp 44-45°C; IR 1675 cm^{-1}; ^1H NMR 2.37 (m, 4H), 2.50 (dd, 1H, J = 12.5, 5.9 Hz), 2.82 (m, 2H), 3.03 (dd, 1H, J = 8.1, 13.6 Hz), 3.52 (m, 4H), 3.93 (m, 1H), 7.30 (m, 8H), 7.76 (d, 2H, J = 7.4 Hz); ^{13}C NMR 36.9, 46.0, 53.7, 60.5, 66.8, 125.9, 126.4, 127.8, 128.0, 128.6, 129.1, 137.7, 139.3, 203.8; MS, m/e 309 (M^+, 2%), 218 (6), 105 (12), 100 (100), 91 (8); UV (CH_3OH) 244 (ε = 10471), 319 nm (ε = 155).

1-(4-Hydroxy-3,5-di-*tert*-butyl)phenyl-2-methyl-3-morpholinopropan-1-one (1r). mp 105°C; IR 3500, 1675 cm^{-1}; ^1H NMR 1.23 (d, 3H), 1.48 (s, 18H), 2.45(m, 5H), 2.81(dd, 1H, J = 8.2, 12.5 Hz), 3.66 (m, 5H), 5.76 (s, 1H), 7.90 (s, 2H); MS, m/e 361 (M^+, 17%), 346 (3), 233 (15), 128 (7), 100 (100); UV (CH_3OH) 285 nm (ε = 12589).

3-Morpholino-1,3-diphenylpropan-1-one (**1m**) was synthesized as described previously.[30] 3-(4-cyano)phenyl-3-morpholino-1-phenylpropan-1-one (**1l**) was prepared by stirring of 3-(4-cyano)phenyl-1-phenylpropen-1-one and morpholine (20% excess) in toluene at 50°C for 8 h. The solvent was evaporated and colorless crystals of **1l** were obtained in 52% yield by recrystallization from diethyl ether/*n*-hexane. 3-(4-methoxy)phenyl-3-morpholino-1-phenylpropan-1-one (**1n**) was prepared by refluxing of 3-(4-methoxy)phenyl-1-phenylpropen-1-one and morpholine (40% excess) in *n*-heptan for 8 h. **1n** crystallized at room temperature and recrystallization from the same solvent gave colorless crystals in 37% yield.

3-(4-Cyano)phenyl-3-morpholino-1-phenylpropan-1-one (1l). mp 70-71°C; IR 2228, 1669 cm^{-1}; ^1H NMR 2.38 (m, 4H), 3.28 (dd, 1H, J = 5.6, 16.8 Hz), 3.54 (dd, 1H, J = 7.5, 16.8 Hz), 3.61 (m, 4H), 4.18 (dd, 1H, J = 5.5, 7.5 Hz), 7.49 (m, 7H), 7.84 (d, 2H, J = 8.1 Hz); MS, m/e 320 (M^+, 3%) 233 (14), 215 (12), 201 (100), 157 (10), 105 (62); UV (CH_3OH) 235 nm (ε = 19055).

3-(4-Methoxy)phenyl-3-morpholino-1-phenylpropan-1-one (1n). mp 68-69°C; IR 1668 cm^{-1}; ^1H NMR 2.84 (m, 4H), 3.29 (dd, 1H, J = 6.3, 15.9 Hz), 3.52 (dd, 1H, J = 7.4, 15.9 Hz), 3.58 (m, 4H), 3.82 (s, 3H), 4.07 (dd, 1H, J = 6.2, 7.3 Hz), 6.9 (d, 2H, J = 9.4 Hz) 7.6 (m, 5H), 7.98 (d, 2H, J = 7.5 Hz); MS, m/e 325 (M^+, 4), 238 (8), 220 (2), 206 (100), 161 (7), 105 (84); UV (CH_3OH) 230 nm (ε = 17783).

2-Aminocyclopropanols 2 by Photolysis of 1m-s. Diethyl ether solutions (0.005 M in **1**) were irradiated under argon (O_2 < 0.1 vpm, Oxisorb Messer-Griesheim) to > 95% conversion of starting material while monitoring the progress of the reaction by HPLC. After solvent removal, the cyclopropanols were recrystallized from chloroform/petrolether. **2n** was purified by chromatography on silica gel with dichloromethane/methanol (30:1).

2-Morpholino-1,2-diphenylcyclopropanol (2m). mp 181°C; IR 3419 cm^{-1}; ^1H NMR 1.40 (d, 1H, J = 5.9 Hz), 1.85 (d, 1H, J = 6.1 Hz), 2.15 (s, 1H), 2.3 (m, 4H), 3.3 (m, 4H), 7.4 (m, 8H), 7.65 (d, 2H, J = 8.1 Hz); ^{13}C NMR 27.6 (C-3), 48.8, 58.9 (C-2), 64.7 (C-1), 66.9, 126.5, 126.8, 127.0, 127.7, 128.1, 131.1, 132.4, 139.4; MS, m/e 295 (M^+, 45%), 236 (18), 190 (35), 176 (100), 132 (20), 117 (43), 105 (45),103 (28), 91 (91) 86 (17); HRMS 295.1572 (calcd), 295.1588 (obsd); UV (CH_3OH) 224 nm (ε = 17147).

2-Morpholino-2-(4-methoxy)phenyl-1-phenylcyclopropanol (2n). mp 75-78°C; IR 3385 cm^{-1}; ^1H NMR 1.33 (d, 1H, J = 5.9 Hz), 1.80 (d, 1H, J = 5.9 Hz), 2.11 (s, 1H), 2.05 (m, 4H), 3.3 (m, 4H), 3.82 (s, 3H), 6.94 (d, 2H, J = 8.8 Hz), 7.3 (m, 5H), 7.64 (d, 2H, J = 8.1Hz); ^{13}C NMR 27.9 (C-3), 48.9, 55.3, 58.5 (C-2), 65.0 (C-1), 66.9, 113.7, 124.6, 126.6, 127.0, 127.1, 132.3, 139.5, 159.2; MS, m/e 325 (M^+, 1%), 266 (16), 220 (7), 206 (83), 162 (12), 147 (65), 133 (100), 132 (23), 105 (98), 91(16), 86 (20); UV (CH_3OH) 230 nm (ε = 11220).

2-Morpholino-3-methyl-1-phenylcyclopropanol (2o). mp 113-116°C; IR 3400 cm^{-1}; ^1H NMR 1.25 (d, 3H, J = 5.1 Hz), 1.44 (m, 1H), 1.86 (d, 1H, J = 4.8 Hz), 2.5 (m 4H), 3.45 (m, 4H), 7.30 (m, 3H), 7.49 (d, 2H, J = 8.1 Hz); ^{13}C NMR 30.4, 26.7 (C-3), 58.7 (C-2), 62.8 (C-1), 66.2, 125.0, 125.5, 126.8, 140.4; MS, m/e 218 (6%), 128 (13), 105 (37), 100(100), 86 (3); UV (CH_3OH) 225 nm (ε = 8318).

2-Morpholino-3-benzyl-1-phenylcyclopropanol (2p). mp 148-149°C; IR 3373 cm^{-1}; ^1H NMR 1.74 (m, 1H), 2.09 (d, 1H, J = 5.2 Hz), 2.25 (m, 5H), 2.92 (dd, 1H, J = 7.4, 15.5 Hz), 2.97 (dd, 1H, J = 7.3, 15.5 Hz), 3.4 (m, 4H), 7.3 (m, 8H), 7.52 (d, 2H, J = 8.1 Hz); ^{13}C NMR 32.5, 34.1 (C-3), 52.1, 58.3 (C-2), 64.0 (C-1), 66.7, 125.5, 126.0, 126.3, 127.4, 128.2, 128.5, 140.6, 141.2; MS, m/e 218 (100%), 140 (4), 131 (4), 115 (12), 105 (93), 100 (30), 91 (21), 86(3); HRMS 309.1729 (calcd), 309.1736 (obsd); UV (CH_3OH) 228 nm (ε = 11220).

2-Morpholino-1,3-diphenylcyclopropanol (2q). mp 149°C; IR 3287 cm^{-1}; ^1H NMR 1.98 (s, 1H), 2.45 (m, 4H), 2.70 (d, 1H, J = 5.8 Hz), 2.75 (d, 1H, J = 5.8 Hz), 3.5 (m, 4H), 7.3 (m, 8H), 7.65 (d, 2H, J = 8.2 Hz); ^{13}C NMR 38.8 (C-3), 52.2, 58.0 (C-2), 64.5 (C-1), 66.8, 125.7, 126.5, 126.8, 127.5, 128.4, 128.8, 135.3, 140.1; MS, m/e 190 (4), 131 (6), 130 (7), 105 (18), 100 (100), 91 (6), 86 (5); HRMS 295.1572 (calcd), 295.1583 (obsd); UV (CH_3OH) 233 nm (ε = 14125).

2-Morpholino-3-methyl-1-(3,5-di-*tert*-butyl-4-hydroxy)phenylcyclopropanol (2r). mp 126-129°C; IR 3409 cm^{-1}; ^1H NMR 1.22 (d, 3H, J = 5.9 Hz), 1.35 (m, 1H), 1.43 (s, 18H), 1.80 (d, 1H, J = 5.2 Hz), 2.35 (m, 5H), 3.45 (m, 4H), 5.07 (s, 1H), 7.34 (s, 2H); MS, m/e 274 (4%), 233 (11), 128 (31), 100 (100), 91 (5), 57 (20); UV (CH_3OH) 233 nm (ε = 8318).

7b-Hydroxy-1-morpholino-1a,7b,2,3-tetrahydro-1*H*-cyclopropa[*a*]naphthalene (2s). mp 131-135°C; IR 3280 cm^{-1}; ^1H NMR 1.75 (m, 1H), 1.88 (s, 1H), 2.0 (m, 1H), 2.10 (d, 1H, J = 4.5 Hz), 2.40 (m, 1H), 2.60 (m, 6H), 3.75 (m, 4H), 7.03 (d, 1H, J = 7.35 Hz), 7.12 (m, 1H), 7.23 (m, 1H), 7.75 (d, 1H, J = 8.1 Hz); ^{13}C NMR 18.5, 27.0, 28.7 (C-3), 53.0, 56.0 (C-2), 59.5 (C-1), 66.9, 124.1, 125.6, 126.3, 128.1, 133.0, 138.0; MS, m/e 228 (4%), 159 (3), 146 (3), 131 (5), 129 (6), 115 (6), 100 (100), 91 (5), 86 (5); UV (CH_3OH) 231 nm (ε = 7943).

Enaminones by Photolysis of 1. 500 ml of methanol solutions, 0.005 M in **1** were irradiated to > 90% conversion of starting material (20-60 h) while monitoring the photoreaction by HPLC. After solvent removal, the oil residues were first chromatographed on Sephadex LH 20 and then on silica gel with dichloromethane/methanol (20:1) or cyclohexane/isopropanol (4:1). The fractions which contained **3** could be identified by the 350 nm CT absorption band. **3d,e,j** and **3m** crystallized after solvent removal. **3a-c, 3f-i, 3k,l** and **3n** were obtained by semipreparative HPLC on silica gel with dichloromethane/methanol (50:1-500:1). **3a**,[31] **3b,c**,[32] **3g**,[33] **3h**,[34] and **3j**,[35] had the same spectroscopic properties as already reported. The coupling constants of 12-13 Hz for the vinylic protons in the ^1H NMR spectra indicate that the α,β-unsubstituted **3a-k** occur as E-isomeres. The two signals for C(α)-H of **3l-n** were assigned to the E/*s-cis* and E/*s-trans* isomeres.[36] The percentages of both isomeres calculated from the integrals of the ^1H-NMR signals indicate that the E/s-*trans* isomeres (**3l**: 94%, **3m**: 71%, **3n**: 71%) are preferred over the E/s-*cis* isomeres. Hydrogenperoxide was detected in the photolysates of **1g** and **1m** by reaction with titaniumoxysulfate-sulphuric acid complex hydrate.

1-(4-Cyano)phenyl-3-piperidinopropen-1-one (3d). mp 157-158°C; IR 2224, 1633, 1573, 1567, 1543 cm^{-1}; ^1H NMR 1.60 (m, 6H), 3.40 (m, 4H), 5.74 (d, 1H, J = 12.4 Hz), 7.65 (d, 2H, J = 8.5 Hz), 7.78 (d, 1H,

J = 12.4 Hz), 7.90 (d, 2H, J = 8.4 Hz); MS m/e 240 (M^+, 50%), 223 (100), 156 (14), 138 (30), 130 (63), 116 (10), 110 (76), 102 (59), 84 (59); UV (CH_3OH) 362 nm (ε = 19953).

1-(4-Cyano)phenyl-3-morpholinopropen-1-one (3e). mp 175-177°C; IR 2226, 1640, 1580, 1550, 1545 cm^{-1}; ^1H NMR 3.39 (m, 4H), 3.76 (m, 4H), 5.80 (d, 1H, J = 12.7 Hz), 7.64 (d, 2H, J = 8.5 Hz), 7.74 (d, 1H, J = 12.6 Hz), 7.85 (d, 2H, J = 8.4 Hz); MS m/e 242 (M^+, 24%), 225 (27), 185 (11), 156 (22), 130 (51), 116 (19), 112 (25), 102 (50), 86 (16); UV (CH_3OH) 359 nm (ε = 12589).

1-(4-Fluoro)phenyl-3-morpholinopropen-1-one (3f). IR ($CHCl_3$) 1641, 1598, 1550 cm^{-1}, ^1H NMR 3.40 (m, 4H), 3.70 (m, 4H), 5.85 (d, 1H, J = 13.0 Hz), 7.10 (dd, 2H, J = 8, 9 Hz) 7.77 (d, 1H, J = 13.0 Hz), 7.98 (dd, 2H, J = 5, 9 Hz); MS m/e 235 (M^+, 15%), 218 (19), 149 (21), 142 (13), 123 (100), 112 (14), 95 (63); UV (CH_3OH) 343 nm (ε = 19953).

1-(4-Acetoxy-3,5-di-*tert*-butyl)phenyl-3-morpholinopropen-1-one (3k). mp 105-107°C; IR 1755, 1640, 1582, 1546 cm^{-1}; ^1H NMR 1.36 (s, 18H), 2.34 (s, 3H), 3.35 (m, 4H), 3.75 (m, 4H), 5.77 (d, 1H, J = 12.9 Hz), 7.70 (d, 1H, J = 12.9 Hz), 7.82 (s, 2H); MS m/e 387 (M^+, 25%), 370 (49), 301 (2), 275 (15), 259 (15), 233 (77), 217 (14), 112 (4), 86 (10); UV (CH_3OH) 344 nm (ε = 15850).

1-Phenyl-3-(4-cyano)phenyl-3-morpholinopropen-1-one (3l). mp 147-150°C; IR 2226, 1629, 1577, 1534 cm^{-1}; ^1H NMR 3.20 (m, 4H), 3.75 (m, 4H), 5.70 (94%) and 6.06 (6%) (s, 1H), 7.40 (m, 5H), 7.69 (d, 2H, J = 8 Hz), 7.79 (d, 2H, J = 7 Hz); MS m/e 318 (M^+, 9%), 301 (100), 213 (15), 156 (7), 128 (24), 116 (10), 105 (54), 102 (14), 91 (14), 86 (20); UV (CH_3OH) 346 nm (ε = 12589).

1,3-Diphenyl-3-morpholinopropen-1-one (3m). mp 97°C; IR 1634, 1575, 1538 cm^{-1}; ^1H N MR 3.18 (m, 4H), 3.70 (m, 4H), 5.64 (70.6%) and 6.05 (29.4%) (s, 1H), 7.45 (m, 8H), 7.80 (d, 2H, J = 8 Hz); MS m/e 293 (M^+, 10%), 276 (100), 246 (4), 216 (4), 207 (5), 156 (7),188 (12), 131 (11), 105 (62), 91 (24), 86 (25); UV (CH_3OH) 344 nm (ε = 19953).

1-Phenyl-3-(4-methoxy)phenyl-3-morpholinopropen-1-one (3n). mp 118-120°C; IR 1630, 1573, 1537 cm^{-1}; ^1H NMR 3.20 (m, 4H), 3.70 (m, 4H), 3.80 (s, 3H), 5.67 (71.4%) and 5.96 (28.6%) (s, 1H), 6.92 (d, 2H, J = 8.1 Hz), 7.35 (m, 5H), 7.82 (d, 2H, J = 7.4 Hz); MS m/e 323 (M^+, 4%), 306 (42), 218 (8), 133 (59), 117 (12), 108 (13), 105 (87), 91 (18), 86 (22), 77 (100); UV (CH_3OH) 348 nm (ε = 15850).

4-Acetoxy-3,5-di-*tert*-butylbenzoic acid formed as minor product by photolysis of **1k** in methanol was isolated by size exclusion chromatography.

4-Acetoxy-3,5-di-*tert*-butyl-benzoic acid. mp 169-172°C, IR 3000, 1778, 1700 cm^{-1}; ^1H NMR 1.38 (s, 18H), 2.36 (s, 3H), 8.10 (s, 2H), 9.0 (s, 1H); MS, m/e 292 (M^+, 2%), 250 (49), 235 (100), 219 (7), 217 (11), 207 (16), 191 (10), 175 (5), 115 (9), 57 (28); UV (CH_3OH) 240 nm.

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