A Visible Light-Driven Minisci-Type Reaction with N-Hydroxyphthalimide Esters

Lisa Marie Kammer, Aliyaah Rahman and Till Opatz*

Institute of Organic Chemistry, Johannes Gutenberg University, Duesbergweg 10-14, 55128 Mainz, Germany

Supporting Information

Table of Contents

I. Reaction Setup for Irradiations	S2
II. Optimization Studies and Control Experiments	S3
III. UV-Vis Spectroscopy Data	S5
IV. NMR Spectra	S10

I. Reaction Setup for Irradiations and Emission spectra

Irradiation was carried out using a blue LED (high power 100 W LED, HPR40E-48K100BG (GalnN/GaN) from Huey Jann Electronic Industry CO,LTD., Taiwan, $\lambda_{max} = 462 \pm 3$ nm). The lamp was placed in a distance of 5 cm from the reaction vessel. No further cooling was necessary to maintain ambient temperature. The setup and the emission spectra are shown in the following pictures.



Figure S1. Setup for irradiation with a 100 W blue LED module



Figure S2. Emission spectra of the 100 W blue LED module. The spectra was recorded with an USB2000+ from Ocean Optics, Inc., Dunedin, Florida, USA. Wavelength range from 200–523 nm, optical resolution 1 nm.

II. Optimization Studies and Control Experiments



Table S1. Catalyst loading study

Procedure: The reactions were performed in a glass vial according to the General Procedure B using *N*-(cyclohexylcarbonyloxy)phthalimide (**1**, 82.0 mg, 0.3 mmol), isoquinoline (**2**, 25.8 mg, 0.2 mmol), Ru(bpy)₃Cl₂, TFA (0.05 mL, 0.6 mmol) and acetonitrile (3 mL). ^a Isolated yield. ^b Judged by HPLC.

0 0 N 0 N 0 1 (1.5 equiv.)	F + () 2 (1 equiv.)	Ru(bpy) ₃ Cl ₂ (2 mol%) TFA (2.5 equiv.) solvent (0.1 M) LED, rt, 48 h
entry	solvent	yield (%) ^a
1	DCM	1
2	MeCN	24%
3	MeCN/H ₂ O (1:1)	36%
4	MeOH	43%
5	DMA	79%
6	DMSO	80%
7	DMF	91%

Table S2. Solvent screening for the photoredox Minisci-type reaction

Procedure: The reactions were performed in a glass vial according to the General Procedure B using N-(cyclohexylcarbonyloxy)phthalimide (**1**, 82.0 mg, 0.3 mmol), isoquinoline (**2**, 25.8 mg, 0.2 mmol), Ru(bpy)₃Cl₂ (4 mg, 2 mol%), TFA (0.05 mL, 0.6 mmol) and the indicated dry solvent (3 mL). ^a Isolated yield.

0 0 N 0 N 0 1 (1.5 equiv.)	Ru(bpy) ₃ Cl ₂ (2 additive (2.5 + <u>DMF (0.1</u> LED, rt, 4 2 (1 equiv.)	$\begin{array}{c} 2 \text{ mol}\%)\\ \text{equiv.})\\ \underline{M})\\ 8 \text{ h} \end{array} \qquad $
entry	additive	yield (%) ^a
1	HOAc	1
2	HOAc ^b	1
3	c	31%
4	H_2SO_4	70%
5	HCI	71%
6	AICI3	74%
7	In(OTf) ₃	79%
8	TFA	91%
9	<i>p-</i> TsOH monohydrate ^d	quant.

Table S3. Additive screening for the photoredox Minisci-type reaction

Procedure: The reactions were performed as described for table S1. ^a Isolated yield. ^b The reaction was performed with 1.5 equiv. of acetic acid and without any further solvent. ^c isoquinolinium triflate (1 equiv.) was used instead of **2**. ^d Same yield was achieved using 2.50 and 1.50 equiv. of the additive. With 1.0 equiv. the yield decreased to 72%.



Table S4. Equivalent screening of isoquinoline

<u>Procedure</u>: The reactions were performed as described for table S1. ^a Isolated yield.

III. UV-Vis Spectroscopy

Absorption spectra of *N*-(cyclohexylcarbonyloxy)phthalimide, isoquinoline and *p*-toluenesulfonic acid monohydrate, as well as the spectra of the reaction mixture before irradiation are depicted in figure S3.









The obtained spectroscopic data shows that the absorption maxima of each compound lie well below 350 nm (figure S3). In all cases, the absorption of each component and mixtures was measured using the same stoichiometric ratio as applied in the general procedure B. Upon product formation the color of the reaction mixture changed from colorless to yellow and further UV-Vis spectra were recorded (figure S3, E and E.1). The overlapping absorption maxima of the single compounds in the area between 290–350 nm did not change, but a new absorption was detected stretching out into the visible range. The occurrence of potential ground state charge-transfer-complexes, which may act as photocatalysts, was investigated by comparing the absorption spectra of mixtures of the reactants with the absorption spectra of the pure compounds (figure S4).







Figure S4. Exclusion of ground state charge-transfer complexes. UV-Vis absorption spectra at 290–500 nm measured for different mixtures of *N*-(cyclohexylcarbonyloxy)phthalimid ($1\cdot10^{-4}$ M), B) isoquinoline ($1\cdot10^{-4}$ M), *p*-toluenesulfonic acid monohydrate ($1\cdot10^{-4}$ M) and D) the reaction mixture ($1\cdot10^{-4}$ M). All spectra were measured in dry. DMF.

The spectra of the two component mixtures (blue) don't show any new absorption maxima in comparison to the spectras measured for the single compounds (green, orange).

IV. NMR Spectra



Figure S5. 1H-NMR in CDCl3 N-(Cyclohexyl-2-carbonyloxy)phthalimide (1)



Figure S6. ¹³C-NMR in CDCl₃ N-(Cyclohexyl-2-carbonyloxy)phthalimide (1)



Figure 8. ¹³C-NMR in CDCl₃ N-(Hexanoyloxy)phthalimide (26)



Figure S9. ¹H-NMR in CDCl₃ N-(Pivaloyloxy)phthalimide (27)



Figure S10. 1H-NMR in CDCl₃ N-(N-tert-Butoxycarbonyl-L-valinyloxy)phthalimide (28)



Figure S12. ¹H-NMR in CDCl₃ *N*-(Isobutyryloxy)phthalimide (29)



Figure S14. ¹³C-NMR in CDCl₃ N-(Pentyl-2-carbonyloxy)phthalimide (30)

Figure S16. ¹³C-NMR in CDCl₃ *N*-(2-Ethylbutyryloxy)phthalimide (31)

Figure S18. ¹³C-NMR in CDCl₃ N-(Pent-4-enyl-2-carbonyloxy)phthalimide (32)

Figure S20. 1H-NMR in CDCl3 N-(2-Phenylacetyloxy)phthalimide (34)

Figure S21. 1 H-NMR in CDCl₃ 1-(Cyclohexyl)isoquinoline (3)

Figure S22. ¹³C-NMR in CDCl₃ 1-(Cyclohexyl)isoquinoline (3)

Figure S24. ¹H-NMR in CDCl₃ 1-(Pentan-3-yl)isoquinoline (6)

Figure S25. 1H-NMR in CDCl3 1-(Pentan-2-yl)isoquinoline (7)

Figure S26. 1H-NMR in CDCl3 1-(Pent-4-en-2-yl)isoquinoline (8)

Figure S28. 1H-NMR in CDCl3 1-(Pentyl)isoquinoline (9)

Figure S29. ¹H-NMR in CDCl₃ tert-Butyl-[1-(isoquinolin-2-yl)-2-methylpropyl]carbamate (11)

Figure S30. ¹³C-NMR in CDCl₃ tert-Butyl-[1-(isoquinolin-2-yl)-2-methylpropyl]carbamate (11)

Figure S32. ¹H-NMR in CDCl₃ 2-(Pentan-2-yl)-1,3-benzothiazole (15)

Figure S34. ¹³C-NMR in CDCl₃ 2-(Pent-4-en-2-yl)-1,3-benzothiazole (16)

Figure S36. 1H-NMR in CDCl3 tert-Butyl-[2-methyl-1-(pyrazin-2-yl)propyl]carbamate (18)

Figure S37. ¹³C-NMR in CDCl₃ tert-Butyl-[2-methyl-1-(pyrazin-2-yl)propyl]carbamate (18)