Iron-Catalyzed Regioselective Oxo- and Hydroxy-Phthalimidation of Styrenes: Access to α-Hydroxyphthalimide Ketones

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Abstract: This paper describes the aerobic oxidation of styrenes catalyzed by iron(III) chloride ($FeCl_3$) to form β-keto-*N*-alkoxyphthalimides in fair to good yields. This oxidative process employs mild conditions with green and atom efficient dioxygen (O_2) as the oxidant.

**Keywords:** aerobic oxidation; arylalkenes; iron catalysts; β-keto-*N*-alkoxyphthalimides

Introduction

Difunctionalization has become a powerful tool for the synthesis of natural products and active pharmaceutical ingredients.[1] Alkene dioxygenation has been elegantly demonstrated with various transition metal catalysts which are often costly and toxic; thus, metal-free alkene dihydroxylation has been developed.[2] Iron is cheap, abundant, and low in toxicity; thus, iron-catalyzed[3] organic reactions have attracted more attention than reactions catalyzed by precious metals, such as Pt, Rh, Ru, and Pd. Olefin epioxidation catalyzed or promoted by Fe-based complexes has been recently developed.[4] Radical difunctionalization has attracted increasing attention in recent years because of its mild conditions, high selectivity, and convenient work-up.[5] The direct dioxygenation of alkenes with acids or methyl *N*-hydroxy-*N*-phenyl-carbamate has been recently accomplished with peroxide as a radical initiator at a moderate temperature (Scheme 1).[6] The Mn(III)- and Cu(II)-catalyzed direct dioxygenation of alkenes with air and a simple *N*-hydroxyphthalimide has been developed to produce β-keto-*N*-alkoxyphthalimides.[7]

We have utilized inexpensive catalysts and atom economical oxidants, such as O_2, to develop a mild, selective, and efficient oxidative Mannich reaction.[8] In this paper, we report the successful development of an intermolecular direct aerobic dioxygenation of styrenes employing *N*-hydroxyphthalimide (NHPI). The aerobic oxidation of styrenes is catalyzed by $FeCl_3$ to form β-keto-*N*-alkoxyphthalimides. This re-action employs mild conditions that use green and atom efficient O_2 as the oxidant.
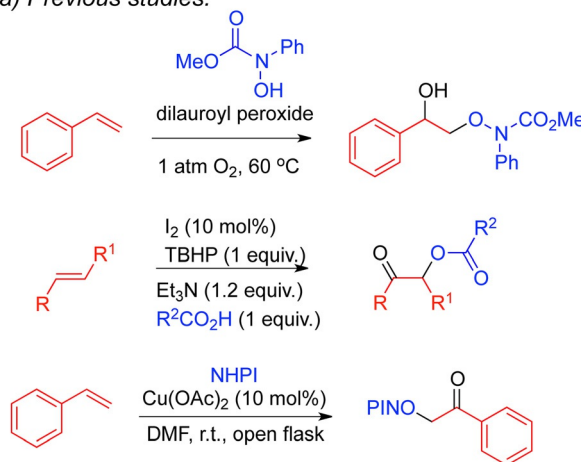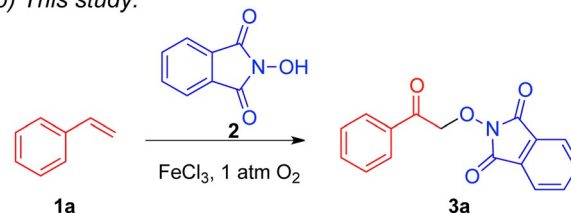
**Scheme 1.** Aerobic dioxygenation of alkenes.

Results and Discussion

We began our studies by utilizing styrene (**1a**, 1.2 equiv.) with *N*-hydroxyphthalimide (**2**, NHPI) as our model materials to optimize reaction conditions. At the onset, β-keto-*N*-alkoxyphthalimide (**3a**) was obtained in 32% yield when treated with 10 mol% FeCl$_3$ in acetonitrile under oxygen (Table 1, entry 1). We screened the reaction in the presence of different solvents (see the Supporting Information) to improve further the efficiency of this procedure, but most of these solvents led to poor yields (entries 2–4). Fortunately, the reaction smoothly proceeded in CH$_3$CN/H$_2$O (9:1), thereby producing **3a** in 56% yield (entry 5). In addition, a hypoxic or anoxic atmosphere proved to be ineffective for this transformation, and no reactions were observed in the absence of a catalyst (entries 6–8). Considering that benzaldehyde was detected in the reaction as a side product,[9] we increased the amount of **1a** properly and optimized its value to 2.5 equiv., which eventually improved the yield to 73% (entries 9–11). Other Fe(III) salts, such as Fe(NO$_3$)$_3$, Fe$_2$(SO$_4$)$_3$, and Fe(OTf)$_3$, were not superior to FeCl$_3$[10] (entries 12–14). Finally, attempts to raise or reduce the reaction temperature decreased the reaction efficiency (entries 15–17).

With the optimized reaction conditions, we investigated the reaction generality by using various arylalkenes. First, we began to screen substrates with substituents on the aryl ring (Table 2). The arylalkenes with the methyl substituent at the *o*-, *m*-, and *p*-positions on the aryl ring were well tolerated, which led to the production of the desired compounds **3b–3d** in yields of 64–70%. During this transformation, styrenes containing chloro, bromo, and fluoro groups at the *p*-position were well tolerated under the given reaction conditions. The corresponding products could be isolated in good yields (**3e–3g**). The reactions of the styrenes **1h–1j**, which contained substituents such as methoxy, *tert*-butyl, and phenyl groups, produced the desired products **3h–3j**, respectively, in 48–72% yields. Furthermore, the 4-trifluoromethyl-substituted substrate **1k** produced the target compound **3k** in 84% yield. The electron-rich and electron-deficient substitute arylalkenes could seemingly be tolerated. Nevertheless, styrenes containing nitro and nitrile groups (**1l** and **1m**, respectively) showed poor performance, and the corresponding products were not observed. These results indicated that substrates bearing strong electron-withdrawing groups were not active in this reaction. Moreover, 1-naphthylalkene (**1n**) could be oxidized to **3n** in 56% yield under the optimized conditions we obtained.

After screening substrates with functional groups on the aryl ring, we examined the reactions of arylalkenes with various substituents on the β-position under the optimized conditions (Table 3). *trans*-Stil-

Table 1. Optimization studies.[a]
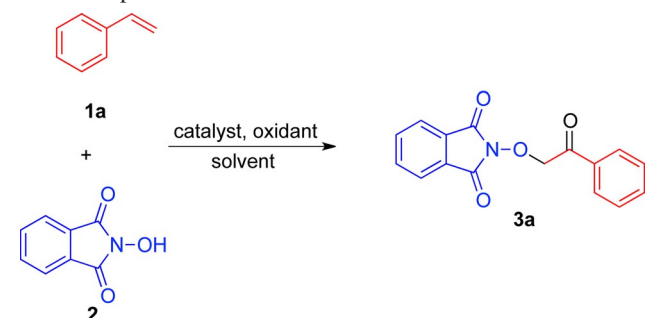
Entry	Styrene [equiv.]	Catalyst	Solvent	Yield [%][b]
1	1.2	FeCl$_3$	CH$_3$CN	32
2	1.2	FeCl$_3$	THF	41
3	1.2	FeCl$_3$	DMF	trace
4[c]	1.2	FeCl$_3$	THF/H$_2$O	18
5	1.2	FeCl$_3$	CH$_3$CN/H$_2$O	56
6[d]	1.2	FeCl$_3$	CH$_3$CN/H$_2$O	46
7[e]	1.2	FeCl$_3$	CH$_3$CN/H$_2$O	40
8	1.2	-	CH$_3$CN/H$_2$O	0
9	2.0	FeCl$_3$	CH$_3$CN/H$_2$O	61
10	**2.5**	**FeCl$_3$**	**CH$_3$CN/H$_2$O**	**73**
11	3.0	FeCl$_3$	CH$_3$CN/H$_2$O	72
12	2.5	Fe(NO$_3$)$_3$	CH$_3$CN/H$_2$O	71
13	2.5	Fe$_2$(SO$_4$)$_3$	CH$_3$CN/H$_2$O	<10
14	2.5	Fe(OTf)$_3$	CH$_3$CN/H$_2$O	68
15[f]	2.5	FeCl$_3$	CH$_3$CN/H$_2$O	13
16[g]	2.5	FeCl$_3$	CH$_3$CN/H$_2$O	62
17[h]	2.5	FeCl$_3$	CH$_3$CN/H$_2$O	67

[a] Alkene (**1a**), NHPI (**2**, 0.3 mmol), catalyst (0.03 mol), CH$_3$CN/H$_2$O (9:1, 2.5 mL), room temperature, 72 h.
[b] Isolated yield.
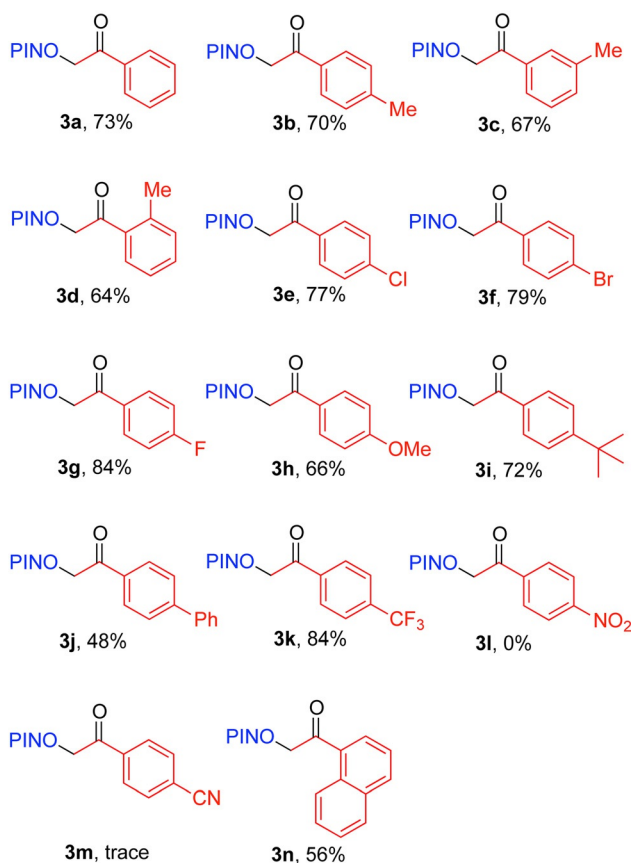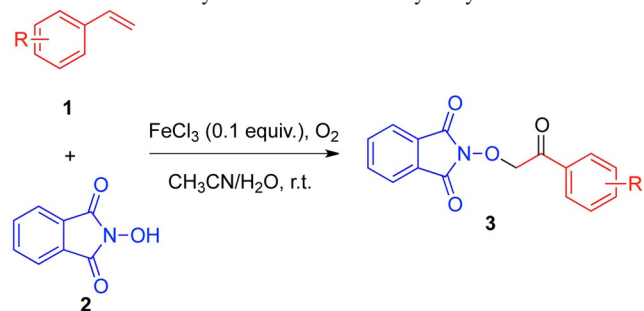[c] THF/H$_2$O (9:1).
[d] Under air.
[e] Under N$_2$.
[f] At 0°C.
[g] At 40°C.
[h] At 60°C.

bene (**4a**) and *cis*-stilbene (**4a′**) were used to investigate the influence of the *cis/trans* isomerization of the alkenes on the reaction; both compounds effectively afforded the desired product **5a** in 65% and 60% yields, respectively. However, when strong electron-withdrawing groups existed at the β-position of the arylalkene, for example in chalcone (**4b**) and *trans*-benzylidenacetone (**4c**), the corresponding products were not obtained even after raising the reaction temperature. Moreover, arylalkenes with alkyl groups on the β-position were all reactive and produced the desired compounds **5d–h** in moderate yields of 32–69%. In addition, the corresponding bromo product **5i** was obtained in 55% yield. Thiophene was also reactive in the reaction, and **5k** was produced in moderate yield. Unsymmetrical stilbenes were also subjected to the

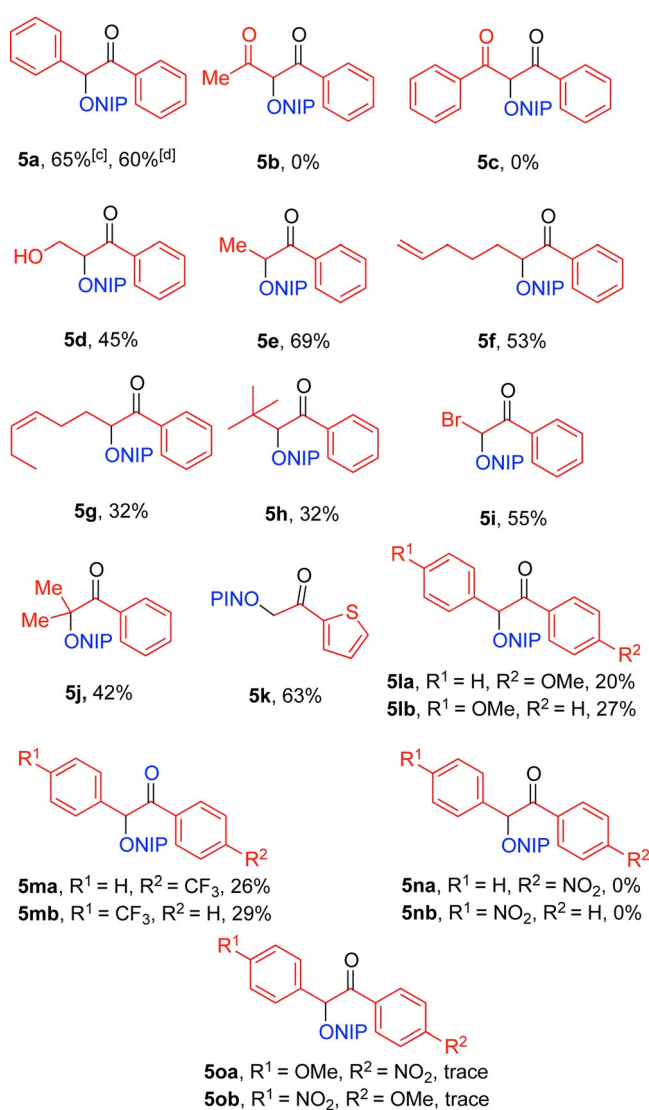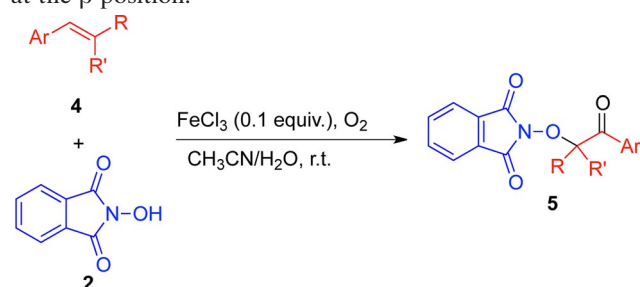**Table 2.** Iron-catalyzed oxidation of arylvinyls.[a,b]

Table 3. Iron-catalyzed oxidation of substituted arylalkenes at the β-position.[a,b]

3a, 73%   **3b**, 70%   **3c**, 67%

3d, 64%   **3e**, 77%   **3f**, 79%

3g, 84%   **3h**, 66%   **3i**, 72%

3j, 48%   **3k**, 84%   **3l**, 0%

3m, trace   **3n**, 56%

5a, 65%[c], 60%[d]   **5b**, 0%   **5c**, 0%

5d, 45%   **5e**, 69%   **5f**, 53%

5g, 32%   **5h**, 32%   **5i**, 55%

5j, 42%   **5k**, 63%   **5la**, R^1 = H, R^2 = OMe, 20%
5lb, R^1 = OMe, R^2 = H, 27%

5ma, R^1 = H, R^2 = CF$_3$, 26%   **5na**, R^1 = H, R^2 = NO$_2$, 0%
5mb, R^1 = CF$_3$, R^2 = H, 29%   **5nb**, R^1 = NO$_2$, R^2 = H, 0%

5oa, R^1 = OMe, R^2 = NO$_2$, trace
5ob, R^1 = NO$_2$, R^2 = OMe, trace

[a] Alkene (**1a–1n**; 0.75 mmol), NHPI (0.3 mmol), FeCl$_3$ (0.03 mmol), CH$_3$CN/H$_2$O (9:1; 2.5 mL), room temperature, O$_2$.
[b] Isolated yield.

[a] Alkene (**4a–4o**; 0.75 mmol), NHPI (0.3 mmol), FeCl$_3$ (0.03 mmol), CH$_3$CN/H$_2$O (9:1; 2.5 mL), room temperature, O$_2$.
[b] Isolated yield.
[c] Using *trans*-stilbene.
[d] Using *cis*-stilbene.

reaction conditions with regard to regioselectivity. The reaction of stilbenes **4l** and **4m** bearing substituents such as methoxy and trifluoromethyl groups produced the regioselective products **5la** and **5lb** or **5ma** and **5mb**, respectively, in moderate yields. However, none of the desired products were detected when stilbenes **4n** and **4o** bearing nitro groups were used.

The protocol was not always applicable when two substituents were introduced at the β-position (Scheme 2). The desired product **5j** was generated, but β-hydroxy-*N*-alkoxyphthalimide (**5p**) was produced in 59% yield under identical conditions. Analo-
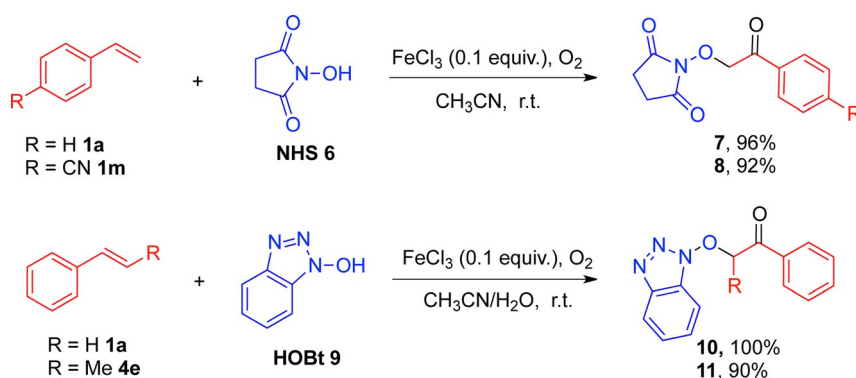
gously, **4q** was oxidized to the alcohols **5q** and **5q′** in 68% and 18% yields, respectively.
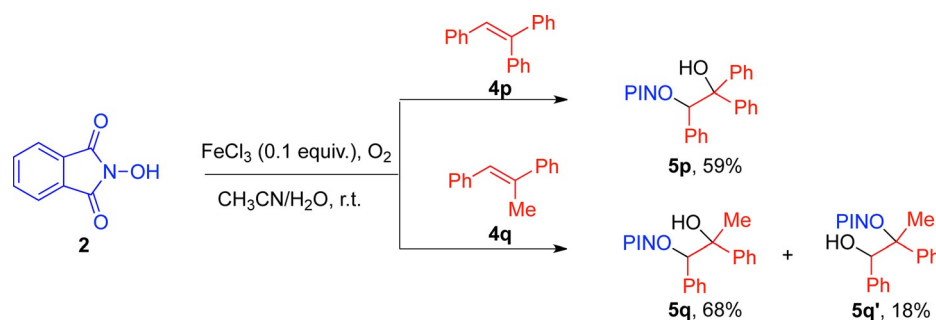
Scheme 2. Oxidation to alcohol under optimized conditions.
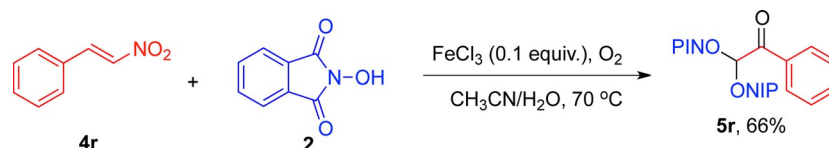
**Scheme 3.** Reaction of *trans*-β-nitrostyrene.


Scheme 4. Reaction of NHS and HOBt.

Notably, arylalkenes with some strong electron-withdrawing groups, such as nitro groups, at the β-position might also produce a related product.[11] Under the optimized conditions, no reaction was observed with **4r** (Scheme 3). However, once the temperature was increased to 70°C, the nitro group was somehow removed, thereby subsequently generating the bis-PINO-substituted compound **5r** in 66% yield.

Subsequently, we explored other hydroxylamines under similar reaction conditions. The oxidation of **1a**, **1m**, and **4e** with NHS and HOBt also produced α-oxygenated ketones (**7**, **8**, **10**, and **11**) in excellent yields (Scheme 4). However, alkenes such as **1l**, **4r**, and **4p** could not afford the desired products. The reason why NHS and HOBt are better than NHIP remains unclear. In the literature, HOBt exhibits much the same reactivity as the nitroxyl radical of NHPI.[7c] Therefore, the reactants could form a complex with the HOBt or NHS radicals to make the compounds more stable and eventually produce excellent yields.

Subsequently, we explored C−O bond cleavage of the β-keto-*N*-alkoxyphthalimide for further functionalization. For example, under Bu₃SnH and AIBN, **3a** was reduced to acetophenone, whereas **5f** could yield the target product **13** in excellent yield (Scheme 5). In addition, the N−O bond cleavage was difficult to ach-
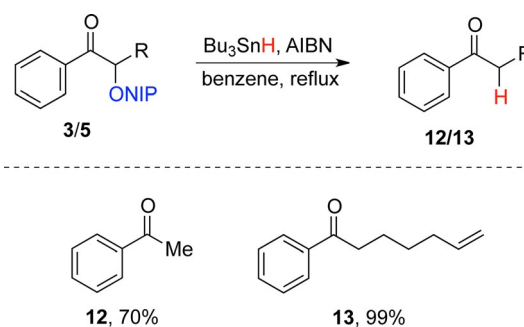
Scheme 5. Reduction experiments.
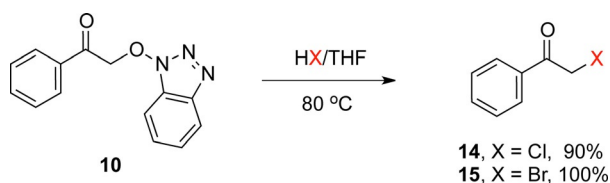
Scheme 6. Reaction with HX.

ieve. Although several methods were attempted (see the Supporting Information), the corresponding α-hydroxy ketone moiety was not obtained.
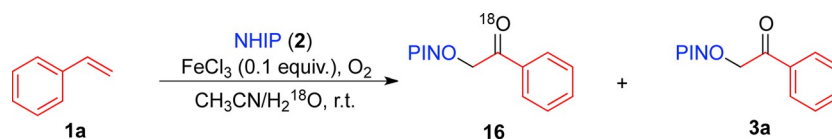
Furthermore, the ketone with the hydroxybenzotriazole moiety (**10**) was easily engaged in the nucleophilic displacement reactions to yield α-halo ketones (**14**, **15**) in excellent yields with aqueous HCl and HBr (Scheme 6).

Isotopic labeling of **1a** was performed as a representative example to explore the proposed reaction pathway (Scheme 7). Target products containing ^{18}O (**16**) or ^{16}O were detected by HR-MS in the reaction with anhydrous CH_3CN, normal O_2, and $H_2^{18}O$, thereby suggesting that the oxygen source may be derived from O_2 and H_2O.
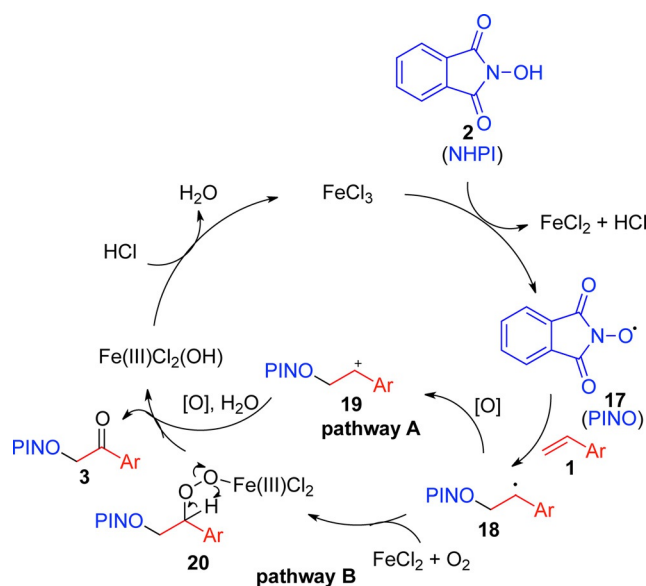
We propose the mechanism for the formation of **3** shown in Scheme 8. After initiation of the reaction *via* the formation of the amidoxyl radical **17**[12] by $FeCl_3$, a radical addition produces the carbon-centered radical **18**, which could participate in two pathways. In pathway A, **18** could be oxidized to the cationic intermediate **19** and eventually be converted to **20** in the presence of H_2O. In pathway B, this intermediate reacts with oxygen and Fe(II) to deliver the alkylhydroperoxy intermediate **20**, which subsequently rearranges to afford α-hydroxyphthalimide ketone and the Fe(III) complex, which reacts with HCl to produce Fe(III) and the by-product H_2O.

Conclusions

We have developed an efficient and practical method to synthesize α-hydroxyphthalimide ketones *via* the simple oxidative functionalization of styrenes. The reaction was carried out under mild conditions with the green and atom efficient O_2 as the oxidant and $FeCl_3$ as the catalyst. The method is applicable to a broad scope of substrates to produce α-hydroxyphthalimide ketones in satisfactory to good yields *via* a novel and environment-friendly one-pot transformation system.

Scheme 8. Proposed mechanism.

Experimental Section

Preparation of Substrates (Derivatives of Styrene)

3-Methylstyrene (1c): *m*-Tolualdehyde (8.3 mmol) was added to a solution of methyltriphenylphosphonium bromide (10 mmol) and K_2CO_3 (13 mmol) in dioxane (7 mL). The mixture was refluxed at 110 °C over 10 h. After being cooled to room temperature, excess solvent was removed by rotary evaporation. The residue was diluted with petroleum ether and filtered through celite and concentrated under vacuum. The crude product was purified by flash column chromatography (petroleum ether) to obtain the corresponding product as a colorless oil; yield: 891 mg (91%). ^1H NMR (400 MHz, $CDCl_3$): $\delta = 7.20–7.18$ (m, 3H), 7.06–7.04 (m, 1H), 6.67 (dd, $J = 17.6$ Hz, 10.9 Hz, 1H) 5.71 (dd, $J = 17.6$ Hz, 0.8 Hz, 1H), 5.20 (dd, $J = 10.9$ Hz, 0.6 Hz, 1H), 2.32 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 21.5$, 113.6, 123.5, 127.1, 128.5, 128.7, 137.1, 137.6, 138.1.

2-Methylstyrene (1d): 2-Methylbenzaldehyde (8.3 mmol) was added to a solution of methyltriphenylphosphonium bromide (10 mmol) and K_2CO_3 (13 mmol) in dioxane (7 mL). The mixture was refluxed at 110 °C over 10 h. After being cooled to room temperature, excess solvent was removed by rotary evaporation. The residue was diluted with petroleum ether and filtered through celite and concentrated under vacuum. The crude product was purified by flash column chromatography (petroleum ether) to obtain the corresponding product as a colorless oil; yield: 930 mg

Scheme 7. Labeling studies

(95%). ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 7.48$–7.45 (m, 1H), 7.19–7.11 (m, 3H), 6.93 (dd, $J = 17.4$ Hz, 11.0 Hz, 1H), 5.63 (d, $J = 17.4$ Hz, 1H), 5.28 (d, $J = 11.0$ Hz, 1H), 2.34 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 19.8$, 115.2, 125.4, 126.1, 127.7, 130.3, 134.9, 135.5, 136.9.

4-Phenylstyrene (1j): 4-Biphenylcarboxaldehyde (5.49 mmol) was added to a solution of methyltriphenylphosphonium bromide (6.68 mmol) and K$_2$CO$_3$ (8.77 mmol) in THF (7 mL). The mixture was refluxed at 75 °C over 10 h. After being cooled to room temperature, excess solvent was removed by rotary evaporation. The residue was diluted with petroleum ether and filtered through celite and concentrated under vacuum. The crude product was purified by flash column chromatography (petroleum ether) to obtain the corresponding product as a white solid; yield: 692 mg (70%); mp 120–122 °C. ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = $ 7.59 (d, $J = 7.4$ Hz, 2H), 7.56 (d, $J = 8.2$ Hz, 2H), 7.48 (d, $J = 8.2$ Hz, 2H) 7.43 (t, $J = 7.4$ Hz, 2H), 7.33 (t, $J = 7.4$ Hz, 1H), 6.75 (dd, $J = 17.6$, 10.9 Hz, 1H), 5.79 (d, $J = 17.6$ Hz, 1H), 5.27 (d, $J = 10.9$ Hz, 1H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = $ 113.9, 126.7, 127.0, 127.3, 127.4, 128.8, 136.4, 136.6, 140.6, 140.8.

4-(Trifluoromethyl)styrene (1k): 4-(Trifluoromethyl)benzaldehyde (2.87 mmol) was added to a solution of methyltriphenylphosphonium bromide (3.36 mmol) and K$_2$CO$_3$ (4.64 mmol) in THF (4 mL). The mixture was refluxed at 75 °C over 10 h. After being cooled to room temperature, excess solvent was removed by rotary evaporation. The residue was diluted with petroleum ether and filtered through celite and concentrated under vacuum. The crude product was purified by flash column chromatography (petroleum ether) to obtain the corresponding product as a colorless oil; yield: 490 mg (99%). ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = $ 7.58 (d, $J = 8.2$ Hz, 2H), 7.49 (d, $J = 8.2$ Hz, 2H), 6.74 (dd, $J = 10.9$, 10.9 Hz, 1H) 5.84 (d, $J = 17.6$ Hz, 1H), 5.88 (d, $J = 10.9$ Hz, 1H); ^{19}F NMR (376 MHz, CDCl$_3$): $\delta = -62.5$ (s, 3F); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 116.5$, 122.8, 125.4 (q, $J = 3.5$ Hz), 126.4, 129.6 (q, $J = 32.2$ Hz), 135.6, 140.9.

4-Cyanostyrene (1m): 4-Cyanobenzaldehyde (3.82 mmol) was added to a solution of methyltriphenylphosphonium bromide (4.58 mmol) and K$_2$CO$_3$ (6.04 mmol) in dioxane (4 mL). The mixture was refluxed at 110 °C over 10 h. After being cooled to room temperature, excess solvent was removed by rotary evaporation. The residue was diluted with petroleum ether and filtered through celite and concentrated under vacuum. The crude product was purified by flash column chromatography (petroleum ether) to obtain the corresponding product as a colorless oil; yield: 483 mg (98%). ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 7.62$ (d, $J = 8.2$ Hz, 2H), 7.49 (d, $J = 8.2$ Hz, 2H), 6.73 (dd, $J = 17.5$, 10.9 Hz, 1H) 5.88 (d, $J = 17.6$ Hz, 1H), 5.45 (d, $J = 10.9$ Hz, 1H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 111.1$, 117.8, 118.9, 126.8, 132.4, 135.4, 141.9.

1-Vinylnaphthalene (1n): 1-Naphthaldehyde (3.85 mmol) was added to a solution of methyltriphenylphosphonium bromide (4.48 mmol) and K$_2$CO$_3$ (5.97 mmol) in THF (6 mL). The mixture was refluxed at 75 °C over 10 h. After being cooled to room temperature, excess solvent was removed by rotary evaporation. The residue was diluted with petroleum ether and filtered through celite and concentrated under vacuum. The crude product was purified by flash column chromatography (petroleum ether) to obtain the

corresponding product as a colorless oil; yield: 591 mg (99%). ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 8.10$ (d, $J = 7.8$ Hz, 1H), 7.83 (d, $J = 7.4$ Hz, 1H), 7.77 (d, $J = 8.2$ Hz, 1H), 7.61 (d, $J = 7.2$ Hz, 1H), 7.52–7.41 (m, 4H), 5.78 (dd, $J = 17.3$ Hz, 1.5 Hz, 1H), 5.46 (dd, $J = 10.9$ Hz, 1.5 Hz, 1H); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 117.2$, 123.7, 123.8, 125.7, 125.8, 126.1, 128.2, 128.6, 131.2, 133.6, 134.4, 135.7.

(Z/E)-β-Methylstyrene (4e): Benzaldehyde (4.72 mmol) was added to a solution of ethyltriphenylphosphonium bromide (5.39 mmol) and K$_2$CO$_3$ (7.25 mmol) in dioxane (4 mL). The mixture was refluxed at 110 °C over 10 h. After being cooled to room temperature, excess solvent was removed by rotary evaporation. The residue was diluted with petroleum ether and filtered through celite and concentrated under vacuum. The crude product was purified by flash column chromatography (petroleum ether) to obtain the corresponding product ($E/Z = 44/56$) as a colorless oil; 480 mg (86%). ^{1}H NMR [400 MHz, CDCl$_3$, signals corresponding to (Z)-isomer]: $\delta = 7.35$–7.26 (m, 4H), 7.23–7.16 (m, 1H), 6.42 (t, $J = 14.1$ Hz, 1H), 5.79 (dq, $J = 11.6$ Hz, 7.2 Hz, 1H), 1.90 (dd, $J = 7.3$ Hz, 1.6 Hz, 3H); ^{13}C NMR [100 MHz, CDCl$_3$, signals corresponding to (Z)-isomer]: $\delta = $ 14.6, 126.4, 126.8, 128.1, 128.8, 129.9, 137.6; ^{1}H NMR [400 MHz, CDCl$_3$, representative signals corresponding to (E)-isomer]: $\delta = 7.35$–7.26 (m, 4H), 7.23–7.16 (m, 1H), 6.42 (t, $J = 14.1$ Hz, 1H), 6.24 (dq, $J = 15.7$ Hz, 6.5 Hz, 1H), 1.88 (dd, $J = 7.9$ Hz, 1.4 Hz, 3H); ^{13}C NMR [100 MHz, CDCl$_3$, representative signals corresponding to (E)-isomer]: $\delta = $ 18.5, 125.7, 125.8, 126.7, 128.5, 131.0, 137.9.

Hepta-1,6-dien-1-ylbenzene (4f): 5-Hexen-1-ol (9.58 mmol) was added to a solution of Dess–Martin periodinane (15.33 mmol) in CH$_2$Cl$_2$. The reaction mixture was stirred at room temperature for 5 h, then filtered and the filtrate was evaporated to dryness at low temperature. Petroleum ether was added and the mixture was filtered after being stirred for a while. Excess petroleum ether was removed by rotary evaporation at low temperature. The subsequent oil was dissolved in 2-propanol (20 mL), then benzyltriphenylphosphonium bromide (11.03 mmol) and LiOH·H$_2$O (45.24 mmol) were added. The reaction mixture was stirred at 70 °C for 8 h. After being cooled to room temperature, excess solvent was removed by rotary evaporation. The residue was quenched with water and extracted with ethyl acetate, and the combined organic layers were dried over Na$_2$SO$_4$, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petroleum ether) to obtain the corresponding product ($E/Z = 57/43$) as a colorless oil; 792 mg (48%). ^{1}H NMR [400 MHz, CDCl$_3$, signals corresponding to (E)-isomer]: $\delta = $ 7.34–7.25 (m, 4H), 7.23–7.16 (m, 1H), 6.38 (d, $J = 16.7$ Hz, 1H), 6.25–6.17 (m, 1H), 5.89–5.74 (m, 1H), 5.05–4.92 (m, 2H), 2.37–2.19 (m, 2H), 2.14–2.05 (m, 2H), 1.60–1.52 (m, 2H); ^{13}C NMR [100 MHz, CDCl$_3$, CDCl$_3$, signals corresponding to (E)-isomer]: $\delta = 28.6$, 32.5, 33.3, 114.7, 126.0, 126.9, 128.5, 130.1, 130.7, 137.9, 138.7; ^{1}H NMR [400 MHz, CDCl$_3$, representative signals corresponding to (Z)-isomer]: $\delta = 7.34$–7.25 (m, 4H), 7.23–7.16 (m, 1H), 6.42 (d, $J = 13$ Hz, 1H), 5.89–5.74 (m, 1H), 5.69–5.62 (m, 1H), 5.05–4.92 (m, 2H), 2.37–2.19 (m, 2H), 2.14–2.05 (m, 2H), 1.60–1.52 (m, 2H); ^{13}C NMR [100 MHz, CDCl$_3$, representative signals corresponding to (Z)-isomer]: $\delta = 28.1$, 29.3, 33.4, 114.7, 126.5, 128.2, 128.8, 129.1, 132.7, 137.8, 138.6.

(5Z)-Octa-1,5-dien-1-ylbenzene (4g): A solution of benzyltriphenylphosphonium bromide (13.34 mmol) and LiOH·H$_2$O (17.79 mmol) in 2-propanol (35 mL) was stirred at room temperature for 30 min, and then *cis*-4-heptenal (11.12 mmol) was added. The reaction mixture was stirred at 70 °C for 10 h. After being cooled to room temperature, excess solvent was removed by rotary evaporation. The residue was diluted with petroleum ether and filtered through celite and concentrated under vacuum. The crude product was purified by flash column chromatography (petroleum ether) to obtain the corresponding product. (*E/Z* = 25/75) as a colorless oil; yield: 1.84 g (88%). ^{1}H NMR [400 MHz, CDCl$_3$, signals corresponding to (*E*)-isomer]: δ = 7.34–7.16 (m, 5H), 6.39 (d, *J* = 14.6, 1H), 6.23 (dt, *J* = 15.7 Hz, 6.4 Hz, 1H), 5.44–5.31 (m, 2H), 2.42–2.16 (m, 4H), 2.05 (p, *J* = 7.3 Hz, 2H), 0.96 (t, *J* = 7.5 Hz, 3H); ^{13}C NMR [100 MHz, CDCl$_3$, signals corresponding to (*E*)-isomer]: δ = 14.4, 20.6, 27.0 33.2, 126.0, 126.9, 128.2, 128.5, 130.1, 130.4, 132.3, 137.8; ^{1}H NMR [400 MHz, CDCl$_3$ 7.34–7.16 (m, 5H), 6.43 (d, *J* = 11.5 Hz, 1H), 5.67 (dt, *J* = 14.3 Hz, 7.2 Hz, 1H), 5.44–5.31 (m, 2H), 2.42–2.16 (m, 4H), 2.05 (p, *J* = 7.3 Hz, 2H), 0.96 (t, *J* = 7.5 Hz, 3H); ^{13}C NMR [100 MHz, CDCl$_3$, representative signals corresponding to (*Z*)-isomer]: δ = 14.4, 20.6, 27.5, 28.8, 126.5, 128.1, 128.2, 128.8, 129.1, 132.4, 137.7.

(Z/E)-1-(3,3-Dimethylbut-1-enyl)benzene (4h): A solution of benzyltriphenylphosphonium bromide (20.79 mmol) and LiOH·H$_2$O (28.57 mmol) in 2-propanol (50 mL) was stirred at room temperature for 30 min, and then trimethylacetaldehyde (17.44 mmol) was added. The reaction mixture was stirred at 70 °C for 8 h. After being cooled to room temperature, excess solvent was removed by rotary evaporation. The residue was quenched with water and extracted with ethyl acetate, and the combined organic layers were dried over Na$_2$SO$_4$, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petroleum ether) to obtain the corresponding product (*E/Z* = 35/65) as a colorless oil; yield: 978 mg (35%). ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.36–7.16 (m, 5H), 6.41 (d, *J* = 12.6 Hz, 0.67H), 6.33–6.22 (m, 0.68H), 5.60 (d, *J* = 12.6 Hz, 0.64H), 1.12 (s, 3.17H), 0.98 (s, 5.85H); ^{13}C NMR (100 MHz, CDCl$_3$, (*Z* isomer): δ = 31.3, 34.2, 126.2, 127.2, 127.6, 129.0, 139.4, 142.7; ^{13}C NMR (100 MHz, CDCl$_3$, *E* isomer): δ = 29.7, 33.4, 124.6, 126.1, 126.8, 128.5, 138.1, 141.9.

(2-Methylprop-1-enyl)benzene (4j): A solution of benzyltriphenylphosphonium bromide (15.47 mmol) and LiOH·H$_2$O (20.71 mmol) in 2-propanol (35 mL) was stirred at room temperature for 30 min, and then acetone (25.86 mmol) was added. The reaction mixture was stirred at 70 °C for 10 h. After being cooled to room temperature, excess solvent was removed by rotary evaporation. The residue was quenched with water and extracted with ethyl acetate and the combined organic layers were dried over Na$_2$SO$_4$, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petroleum ether) to obtain the corresponding product. as a colorless oil; yield: 1.225 g (60%). ^{1}H NMR (400 MHz, CDCl$_3$): δ = 7.30 (t, *J* = 7.5 Hz, 2H), 7.21 (d, *J* = 7.4 Hz, 2H), 7.16 (t, *J* = 7.3 Hz, 1H), 6.27 (s, 1H), 1.89 (d, *J* = 1.0 Hz, 3H), 1.85 (d, *J* = 1.0 Hz, 3H); ^{13}C NMR (100 MHz, CDCl$_3$): δ = 19.4, 26.9, 125.2, 125.8, 128.1, 128.8, 135.5, 138.8.

(*E*)-1-Methoxy-4-styrylbenzene (4l): Iodobenzene (4.10 mmol) and 4-methoxystyrene (3.73 mmol) were added to a solution of AgOAc (4.10 mmol) and Pd(OAc)$_2$ (0.37 mmol) in HOAc (8 mL). The reaction mixture was stirred at 110 °C for about 2 h. After being cooled to room temperature, the residue was diluted with ethyl acetate. The resulting solids were removed by filtration and the filtrate was gathered under vacuum. The crude product was purified by flash column chromatography (2–5% EtOAc/petroleum ether) to obtain the corresponding product as a white solid; yield: 768 mg (98%); mp 132–135 °C. ^{1}H NMR (600 MHz, CDCl$_3$): δ = 7.49 (d, *J* = 7.5 Hz, 2H), 7.46 (d, *J* = 7.7 Hz, 2H), 7.34 (t, *J* = 7.3 Hz, 2H), 7.23 (t, *J* = 7.3 Hz, 1H), 7.07 (d, *J* = 16.3 Hz, 1H), 6.98 (d, *J* = 16.3 Hz, 1H), 6.90 (d, *J* = 7.9 Hz, 2H), 3.83 (s, 3H); ^{13}C NMR (150 MHz, CDCl$_3$): δ = 55.3, 114.1, 126.3, 126.6, 127.2, 127.7, 128.2, 128.7, 130.2, 137.7, 159.3.

(E/Z)-1-Styryl-4-(trifluoromethyl)benzene (4m/4m′): A solution of benzyltriphenylphosphonium bromide (6.93 mmol) and LiOH·H$_2$O (17.14 mmol) in isopropanol (20 mL) was stirred at room temperature for 30 min, and then 4-(trifluoromethyl)benzaldehyde (5.74 mmol) was added. The reaction mixture was stirred at 75 °C for 6 h. After being cooled to room temperature, excess solvent was removed by rotary evaporation. The residue was quenched with water and extracted with ethyl acetate and the combined organic layers were dried over Na$_2$SO$_4$, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petroleum ether) to obtain the corresponding product (*E/Z* = 51/49); (*E*)-isomer: white solid; yield: 684 mg (48%); mp: 131–133 °C. ^{1}H NMR (600 MHz, CDCl$_3$): δ = 7.59 (s, 4H), 7.53 (d, *J* = 7.6 Hz, 2H), 7.38 (t, *J* = 7.4 Hz, 2H), 7.30 (t, *J* = 7.4 Hz, 1H), 7.19 (d, *J* = 16.3 Hz, 1H), 7.11 (d, *J* = 16.3 Hz, 1H); ^{19}F NMR (564 MHz, CDCl$_3$): δ = −62.4 (s, 3F); ^{13}C NMR (150 MHz, CDCl$_3$): δ = 124.2 (d, *J* = 270.1 Hz), 125.65 (q, *J* = 4.0 Hz), 126.6, 126.8, 127.1, 128.3, 128.8, 129.26 (q, *J* = 32.4 Hz), 131.2, 136.6, 140.8; (*Z*)-isomer: light oil; yield: 669 mg (47%); ^{1}H NMR (600 MHz, CDCl$_3$): δ = 7.45 (d, *J* = 7.9 Hz, 2H), 7.32 (d, *J* = 7.9 Hz, 2H), 7.24–7.19 (m, 5H), 6.70 (d, *J* = 12.2 Hz, 1H), 6.57 (d, *J* = 12.2 Hz, 1H); ^{19}F NMR (564 MHz, CDCl$_3$): δ = −62.5 (s, 3F); ^{13}C NMR (150 MHz, CDCl$_3$): δ = 121.5, 123.3, 125.19 (q, *J* = 14.2 Hz), 127.6, 128.5, 128.8, 128.9, 129.2, 132.4, 136.6, 140.9.

(E/Z)-1-Nitro-4-styrylbenzene (4n/4n′): A solution of benzyltriphenylphosphonium bromide (12.01 mmol) and LiOH·H$_2$O (29.76 mmol) in 2-propanol (40 mL) was stirred at room temperature for 30 min, and then 4-nitrobenzaldehyde (9.93 mmol) was added. The reaction mixture was stirred at 75 °C for 6 h. After being cooled to room temperature, excess solvent was removed by rotary evaporation. The residue was quenched with water and extracted with ethyl acetate and the combined organic layers were dried over Na$_2$SO$_4$, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography (petroleum ether) to obtain the corresponding product (*E/Z* = 62/38); (*E*)-isomer, yellow solid; yield: 1.162 g (52%); mp 155–158 °C; ^{1}H NMR (600 MHz, CDCl$_3$): δ = 8.21 (d, *J* = 8.2 Hz, 2H), 7.62 (d, *J* = 8.3 Hz, 2H), 7.55 (d, *J* = 7.6 Hz, 2H), 7.40 (t, *J* = 7.3 Hz, 2H), 7.33 (t, *J* = 7.4 Hz, 1H), 7.26 (d, *J* = 16.1 Hz, 1H), 7.14 (d, *J* = 16.3 Hz, 1H); ^{13}C NMR (150 MHz, CDCl$_3$): δ = 124.2, 126.3, 126.9,127.0,

128.88, 128.93, 133.3, 136.2, 143.9, 146.8; (Z)-isomer: yellow solid; yield: 715 mg (32%); mp: 62–64 °C. ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 8.07$ (d, $J = 8.0$ Hz, 2H), 7.37 (d, $J = 8.2$ Hz, 2H), 7.27–7.24 (m, 3H), 7.21–7.18 (m, 2H), 6.81 (d, $J = 12.2$ Hz, 1H), 6.61 (d, $J = 12.2$ Hz, 1H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 123.6$, 127.98, 128.01, 128.6, 128.8, 129.7, 134.0, 136.1, 144.2, 146.5.

(E)-1-Methoxy-4-(4-nitrostyryl)benzene (4o): 4-Iodoanisole (1.81 mmol) and 4-nitrostyrene (1.64 mmol) were added to a solution of AgOAc (1.81 mmol) and Pd(OAc)$_2$ (0.16 mmol) in HOAc (6 mL). The reaction mixture was stirred at 110 °C for about 1 h. After being cooled to room temperature, the residue was diluted with ethyl acetate. The resulting solids were removed by filtration and the filtrate was gathered under vacuum. The crude product was purified by flash column chromatography (2–5% EtOAc/petroleum ether) to obtain the corresponding product as a yellow solid; yield: 356 mg (85%); mp 129–131 °C. ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 8.20$ (d, $J = 8.0$ Hz, 2H), 7.59 (d, $J = 8.0$ Hz, 2H), 7.49 (d, $J = 7.9$ Hz, 2H), 7.22 (d, $J = 16.3$ Hz, 1H), 7.00 (d, $J = 16.3$ Hz, 1H), 6.93 (d, $J = 7.9$ Hz, 2H), 3.85 (s, 3H); ^{13}C NMR (150 MHz, CDCl$_3$) δ 55.4, 114.4, 124.1, 124.2, 126.5, 128.4, 129.0, 132.9, 144.3, 146.4, 160.3.

Triphenylethylene (4p): Iodobenzene (6.12 mmol) and *trans*-stilbene (5.56 mmol) were added to a solution of AgOAc (6.12 mmol) and Pd(OAc)$_2$ (0.28 mmol) in HOAc (15 mL). The reaction mixture was stirred at 110 °C for 1 h. After being cooled to room temperature, the residue was diluted with ethyl acetate. The resulting solids were removed by filtration and the filtrate was gathered under vacuum. The crude product was purified by flash column chromatography (petroleum ether) to obtain the corresponding product as a colorless to yellow oil; yield: 1.254 g (88%). ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 7.32$–7.26 (m, 8H), 7.23–7.19 (m, 2H), 7.14–7.09 (m, 3H), 7.02 (d, $J = 11.3$ Hz, 2H), 6.96 (s, 1H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 126.8$, 127.4, 127.5, 127.6, 128.0, 128.20, 128.24, 128.7, 129.6, 130.4, 137.4, 140.4, 142.6, 143.5.

General Procedure for the Preparation of 2-(2-Oxo-2-phenylethoxy)isoindoline-1,3-dione and its Derivatives

Styrene (0.77 mmol) and FeCl$_3$ (0.031 mmol) were added to a solution of *N*-hydroxyphthalimide (0.31 mmol) in CH$_3$CN and H$_2$O (9:1; 2.5 mL). A balloon charged with O$_2$ was added, and the reaction tube was evacuated and backfilled with O$_2$ thrice. The resulting solution was stirred at room temperature for nearly 72 h. The mixture was poured into water and extracted with ethyl acetate. The combined organic layers were dried over Na$_2$SO$_4$, filtered, and then concentrated under reduced pressure. The crude residue was purified by flash column chromatography (gradient eluent: 15–20% ethyl acetate in hexanes) to afford the desired compound. Other derivatives were similarly prepared.

2-(2-Oxo-2-phenylethoxy)isoindoline-1,3-dione (3a): Following the general procedure: white solid; yield: 64 mg (73%); mp 127–129 °C; $R_f = 0.43$ (30% EtOAc/petroleum ether); ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 8.01$ (d, $J = 7.2$ Hz, 2H), 7.87–7.82 (m, 2H), 7.78–7.73 (m, 2H), 7.62 (t, $J = 7.4$ Hz, 1H), 7.50 (t, $J = 7.8$ Hz, 2H), 5.45 (s, 2H); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 78.5$, 123.7, 128.3, 128.8, 128.9, 134.1, 134.4, 134.7, 163.0, 192.2; MS (ESI): m/e (% relative intensity) = 282.0 (100) (M+H)$^+$; HR-MS: $m/e = 304.0578$, calcd. for C$_{16}$H$_{11}$NO$_4$ (M+Na)$^+$: 304.0586.

2-[2-Oxo-2-(p-tolyl)ethoxy]isoindoline-1,3-dione (3b): Following the general procedure using *p*-methylstyrene in place of styrene: white solid; yield: 64 mg (70%); mp 160–162 °C; $R_f = 0.46$ (30% EtOAc/petroleum ether); ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 7.90$ (d, $J = 8.2$ Hz, 2H), 7.87–7.82 (m, 2H), 7.78–7.73 (m, 2H), 7.29 (d, $J = 8.0$ Hz, 2H), 5.42 (s, 2H), 2.42 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 21.8$, 78.4, 123.7, 128.4, 128.9, 129.6, 132.0, 134.7, 145.1, 163.0, 191.8; MS (ESI): m/e (% relative intensity) = 296.2 (100) (M+H)$^+$; HR-MS: $m/e = 318.0741$, calcd. for C$_{17}$H$_{13}$NO$_4$ (M+Na)$^+$: 318.0742.

2-[2-Oxo-2-(m-tolyl)ethoxy]isoindoline-1,3-dione (3c): Following the general procedure using 3-methylstyrene in place of styrene: white solid; yield: 63 mg (69%); mp 134–136 °C; $R_f = 0.42$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 7.87$–7.84 (m, 2H), 7.82 (s, 1H), 7.80–7.75 (m, 3H), 7.43 (d, $J = 7.5$ Hz, 1H), 7.39 (t, $J = 7.6$ Hz, 1H), 5.45 (s, 2H), 2.42 (s, 3H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 21.3$, 78.5, 123.7, 125.5, 128.7, 128.8, 128.9, 134.4, 134.7, 134.9, 138.8, 163.0, 192.4; MS (ESI): m/e (% relative intensity) = 296.0 (100) (M+H)$^+$; HR-MS: $m/e = 296.0922$, calcd. for C$_{17}$H$_{13}$NO$_4$ (M+H)$^+$ 296.0923.

2-[2-Oxo-2-(o-tolyl)ethoxy]isoindoline-1,3-dione (3d): Following the general procedure using 2-methylstyrene in place of styrene: white solid; yield: 59 mg (64%); mp 142–145 °C; $R_f = 0.46$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 7.86$–7.84 (m, 2H), 7.78–7.75 (m, 3H), 7.44 (t, $J = 7.4$ Hz, 1H), 7.31 (t, $J = 7.3$ Hz, 2H), 5.34 (s, 2H), 2.57 (s, 3H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 21.4$, 79.4, 123.7, 125.8, 128.8, 129.2, 132.4, 132.5, 134.1, 134.7, 139.8, 163.0, 195.3; MS (ESI): m/e (% relative intensity) = 296.1 (100) (M+H)$^+$; HR-MS: $m/e = 296.0923$, calcd. for C$_{17}$H$_{13}$NO$_4$ (M+H)$^+$: 296.0923.

2-[2-(4-Chlorophenyl)-2-oxoethoxy]isoindoline-1,3-dione (3e): Following the general procedure using 4-chlorostyrene in place of styrene: white solid; yield: 75 mg (77%); mp 142–145 °C; $R_f = 0.52$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 8.00$ (d, $J = 8.5$ Hz, 2H), 7.87–7.83 (m. 2H), 7.79–7.75 (m, 2H), 7.49 (d, $J = 8.5$ Hz, 2H), 5.38 (s, 2H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 78.7$, 123.8, 128.8, 129.2, 130.0, 132.8, 134.8, 140.7, 163.0, 191.3; MS (ESI): m/e (% relative intensity) = 316.6 (100) (M+H)$^+$; HR-MS: $m/e = 316.0384$, calcd. for C$_{16}$H$_{10}$ClNO$_4$ (M+H)$^+$: 316.0377.

2-[2-(4-Bromophenyl)-2-oxoethoxy]isoindoline-1,3-dione (3f): Following the general procedure using 4-bromostyrene in place of styrene: white solid; yield: 88 mg (79%); mp 169–172 °C; $R_f = 0.48$ (30% EtOAc/petroleum ether); ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 7.91$ (d, $J = 8.6$ Hz, 2H), 7.87–7.82 (m, 2H), 7.79–7.76 (m, 2H), 7.66 (d, $J = 8.5$ Hz, 2H), 5.37 (s, 2H); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 78.7$, 123.8, 128.8, 129.5, 130.0, 132.2, 133.2, 134.8, 163.0, 191.5; MS (ESI): m/e (% relative intensity) = 360.2 (100) (M+H)$^+$; $m/e = 359.9871$, calcd. for C$_{16}$H$_{10}$BrNO$_4$ (M+H)$^+$: 359.9871.

2-[2-(4-Fluorophenyl)-2-oxoethoxy]isoindoline-1,3-dione (3g): Following the general procedure using 4-fluorostyrene in place of styrene: white solid; yield: 78 mg (84%); mp 153–156 °C; $R_f = 0.51$ (30% EtOAc/petroleum ether); ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 8.11$–8.08 (m, 2H), 7.88–

7.83 (m, 2H), 7.79–7.75 (m, 2H), 7.19 (t, $J = 8.6$ Hz, 2H), 5.38 (s, 2H); ^{19}F NMR (376 MHz, CDCl$_3$): $\delta = -102.9$–103.0 (m, 1F); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 78.7$, 116.1 (d, $J = 21.9$ Hz), 123.8, 128.8, 131.3, 131.4, 134.8, 163.0, 166.3 (d, $J = 254.9$ Hz) 190.9; MS (ESI): m/e (% relative intensity) = 322.0 (100) (M+Na)$^+$; HR-MS: $m/e = 300.0667$, calcd. for C$_{16}$H$_{10}$FNO$_4$ (M+H)$^+$: 300.0672.

2-[2-(4-Methoxyphenyl)-2-oxoethoxy]isoindoline-1,3-dione (3h): Following the general procedure using 4-methoxystyrene in place of styrene: white solid; yield: 64 mg (66%); mp 133–135°C; $R_f = 0.33$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 8.01$ (d, $J = 8.8$ Hz, 2H), 7.86–7.83 (m, 2H), 7.78–7.75 (m, 2H), 6.97 (d, $J = 8.8$ Hz, 2H), 5.39 (s, 2H), 3.88 (s, 3H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 55.6$, 78.5, 114.1, 123.7, 127.5, 128.8, 130.8, 134.7, 163.0, 164.2, 190.7; MS (ESI): m/e (% relative intensity) = 312.2 (100) (M+H)$^+$; HR-MS: $m/e = 312.0875$, calcd. for C$_{17}$H$_{13}$NO$_5$ (M+H)$^+$: 312.0872.

2-{2-[4-(tert-Butyl)phenyl]-2-oxoethoxy}isoindoline-1,3-dione (3i): Following the general procedure using 4-tert-butylstyrene in place of styrene: white solid; yield: 75 mg (72%); mp 162–164°C; $R_f = 0.55$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 7.95$ (d, $J = 7.8$ Hz, 2H), 7.89–7.82 (m, 2H), 7.79–7.73 (m, 2H), 7.51 (d, $J = 7.8$ Hz, 2H), 5.44 (s, 2H), 1.34 (s, 9H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 31.0$, 35.3, 78.4, 123.7, 125.8, 128.3, 128.8, 131.9, 134.7, 158.0, 163.0, 191.8; MS (ESI): m/e (% relative intensity) = 338.4 (100) (M+H)$^+$; HR-MS: $m/e = 360.1207$, calcd for C$_{20}$H$_{19}$NO$_4$ (M+Na)$^+$: 360.1212.

2-[2-([1,1′-Biphenyl]-4-yl)-2-oxoethoxy]isoindoline-1,3-dione (3j): Following the general procedure using 4-vinylbiphenyl in place of styrene: white solid; yield: 65 mg (59%); mp 168–171°C; $R_f = 0.36$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 8.09$ (d, $J = 8.4$ Hz, 2H), 7.87–7.86 (m, 2H), 7.78–7.75 (m, 2H), 7.73 (d, $J = 8.4$ Hz, 2H), 7.63 (d, $J = 7.3$ Hz, 2H), 7.48 (t, $J = 7.4$ Hz, 2H), 7.41 (t, $J = 7.3$ Hz, 1H), 5.49 (s,2H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 78.6$, 123.8, 127.3, 127.5, 128.5, 128.8, 128.97, 129.03, 133.1, 134.7, 139.6, 146.8, 163.1, 191.9; MS (ESI): m/e (% relative intensity) = 358.2 (100) (M+H)$^+$; HR-MS: $m/e = 358.1072$, calcd. for C$_{22}$H$_{15}$NO$_4$ (M+H)$^+$: 358.1079.

2-{2-Oxo-2-[4-(trifluoromethyl)phenyl]ethoxy}isoindoline-1,3-dione (3k): Following the general procedure using 4-(trifluoromethyl)styrene in place of styrene: white solid; yield: 91 mg (84%); mp 149–152°C; $R_f = 0.46$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 8.18$ (d, $J = 8.1$ Hz, 2H), 7.88–7.84 (m, 2H), 7.80–7.76 (m, 4H), 5.41 (s, 2H); ^{19}F NMR (564 MHz, CDCl$_3$): $\delta = -63.3$ (s, 3F); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 78.9$, 123.4 (d, $J = 271.2$ Hz), 123.8, 125.9 (q, $J = 3.4$ Hz), 128.7, 129.0, 134.8, 135.2 (q, $J = 32.8$ Hz), 137.1, 163.0, 191.7; MS (ESI): m/e (% relative intensity) = 349.9 (100) (M+H)$^+$; HR-MS: $m/e = 350.0639$, calcd. for C$_{17}$H$_{10}$F$_3$NO$_4$ (M+H)$^+$: 350.0640.

2-[2-(Naphthalen-1-yl)-2-oxoethoxy]isoindoline-1,3-dione (3n): Following the general procedure using 1-vinylnaphthalene in place of styrene: white solid,; yield: 58 mg (56%); mp 161–164°C; $R_f = 0.40$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 8.78$ (d, $J = 8.6$ Hz, 1H), 8.05 (t, $J = 8.0$ Hz, 2H), 7.88 (d, $J = 8.1$ Hz, 1H), 7.85–7.81 (m, 2H), 7.76–7.72 (m, 2H), 7.62 (t, $J = 7.7$ Hz, 1H), 7.57–7.52 (m, 2H), 5.48 (s, 2H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 79.5$, 123.7, 124.3, 125.7, 126.8, 128.5, 128.6, 128.8, 129.3,

130.5, 131.7, 134.0, 134.2, 134.7, 163.1, 195.4; MS (ESI): m/e (% relative intensity) = 332.2 (100) (M+H)$^+$; HR-MS: $m/e = 354.0738$, calcd. for C$_{20}$H$_{13}$NO$_4$ (M+Na)$^+$: 354.0742.

2-(2-Oxo-1,2-diphenylethoxy)isoindoline-1,3-dione (5a): Following the general procedure using trans-stilbene or cis-stilbene in place of styrene: white solid; yield: 72 mg (65%) and 67 mg (65%), respectively; mp 162–164°C; $R_f = 0.54$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 8.01$ (d, $J = 7.9$ Hz, 2H), 7.77–7.75 (m, 2H), 7.71–7.68 (m, 2H), 7.63–7.61 (m, 2H), 7.52 (t, $J = 7.3$ Hz, 1H), 7.41 (t, $J = 7.6$ Hz, 2H), 7.36–7.35 (m, 3H), 6.77 (s, 1H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 88.3$, 123.6, 128.67, 128.72, 129.0, 129.1, 129.5, 130.1, 132.6, 133.7, 134.5, 134.7, 163.2, 192.8; MS (ESI): m/e (% relative intensity) = 357.9 (100) (M+H)$^+$; HR-MS: $m/e = 358.1079$, calcd. for C$_{22}$H$_{15}$NO$_4$ (M+H)$^+$: 358.1079.

2-[(3-Hydroxy-1-oxo-1-phenylpropan-2-yl)oxy]isoindoline-1,3-dione (5d): Following the general procedure using cinnamyl alcohol in place of styrene: colorless oil; yield: 44 mg (45%); $R_f = 0.21$ (30% EtOAc/petroleum ether); ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 8.08$ (d, $J = 7.2$ Hz, 2H), 7.86–7.82 (m, 2H), 7.80–7.76 (m, 2H), 7.61 (t, $J = 7.3$ Hz, 1H), 7.50 (t, $J = 7.8$ Hz, 2H), 5.53 (q, $J = 4.2$ Hz, 1H), 4.19–4.13 (m, 1H), 4.05–4.01 (m, 1H); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 60.8$, 88.5, 124.0, 128.6, 128.8, 129.0, 133.9, 135.0, 135.1, 164.3, 193.8; MS (ESI): m/e (% relative intensity) = 312.1 (100) (M+H)$^+$; $m/e = 312.0872$, calcd. for C$_{17}$H$_{13}$NO$_5$ (M+H)$^+$: 312.0872.

2-[(1-Oxo-1-phenylpropan-2-yl)oxy]isoindoline-1,3-dione (5e): Following the general procedure using (Z/E)-β-methylstyrene in place of styrene: colorless oil; yield: 63 mg (69%); $R_f = 0.54$ (30% EtOAc/petroleum ether); ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 8.16$ (d, $J = 7.3$ Hz, 2H), 7.84–7.80 (m, 2H), 7.77–7.73 (m, 2H), 7.60 (t, $J = 7.4$ Hz, 1H), 7.50 (t, $J = 7.8$ Hz, 2H), 5.75 (q, $J = 6.7$ Hz, 1H), 1.69 (d, $J = 6.7$ Hz, 3H); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 16.2$, 83.6, 123.7, 128.7, 128.8, 129.2, 133.8, 134.68, 134.73, 163.7, 195.3; MS (ESI): m/e (% relative intensity) = 296.1 (100) (M+H)$^+$; HR-MS: $m/e = 296.0923$, calcd. for C$_{17}$H$_{13}$NO$_4$ (M+H)$^+$: 296.0923.

2-[(1-Oxo-1-phenylhept-6-en-2-yl)oxy]isoindoline-1,3-dione (5f): Following the general procedure using hepta-1,6-dien-1-ylbenzene in place of styrene: colorless oil; yield: 57 mg (53%); $R_f = 0.60$ (30% EtOAc/petroleum ether); ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 8.07$ (d, $J = 7.7$ Hz, 2H), 7.82–7.77 (m, 2H), 7.75–7.71 (m, 2H), 7.59 (t, $J = 7.2$ Hz, 1H), 7.48 (t, $J = 7.7$ Hz, 2H), 5.83–5.73 (m, 1H), 5.60 (t, $J = 6.0$ Hz, 1H), 5.04–4.94 (m, 2H), 2.16 (q, $J = 7.0$ Hz, 2H), 2.07 (p, $J = 7.8$ Hz, 2H), 1.73 (p, $J = 7.6$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 24.3$, 30.8, 33.2, 88.1, 115.3, 123.6, 128.7, 128.8, 129.0, 133.8, 134.6, 134.9, 137.9, 163.4, 195.9; MS (ESI): m/e (% relative intensity) = 350.1 (100) (M+H)$^+$; HR-MS: $m/e = 372.1213$, calcd. for C$_{21}$H$_{19}$NO$_4$ (M+Na)$^+$: 372.1212.

(Z)-2-[(1-Oxo-1-phenyloct-5-en-2-yl)oxy]isoindoline-1,3-dione (5g): Following the general procedure using (5Z)-octa-1,5-dien-1-ylbenzene in place of styrene: colorless oil; yield: 36 mg (32%); $R_f = 0.65$ (30% EtOAc/petroleum ether); ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 8.08$ (d, $J = 7.9$ Hz, 2H), 7.81–7.78 (m, 2H), 7.74–7.71 (m, 2H), 7.59 (t, $J = 7.3$ Hz, 1H), 7.48 (t, $J = 7.8$ Hz, 2H), 5.62 (t, $J = 5.8$ Hz, 1H), 5.47–5.33 (m, 2H), 2.43–2.28 (m, 2H), 2.18–1.98 (m, 4H),

0.97–0.87 (m, 3H); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 14.2$, 20.5, 22.9, 31.5, 87.5, 123.6, 126.9, 128.7, 128.8, 129.0, 133.6, 133.7, 134.6, 135.0, 163.5, 195.7; MS (ESI): m/e (% relative intensity) = 364.0 (100) (M+H)$^+$; HR-MS: $m/e = 364.1549$, calcd. for C$_{22}$H$_{21}$NO$_4$ (M+H)$^+$: 364.1549.

2-[(3,3-Dimethyl-1-oxo-1-phenylbutan-2-yl)oxy]isoindoline-1,3-dione (5h): Following the general procedure using (Z/E)-(3,3-dimethylbut-1-en-1-yl)benzene in place of styrene: white solid; yield: 34 mg (32%); mp 131–132 °C; $R_f =$ 0.66 (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 7.94$ (d, $J = 7.3$ Hz, 2H), 7.78–7.75 (m, 2H), 7.72–7.68 (m, 2H), 7.55 (t, $J = 7.4$ Hz, 1H), 7.43 (t, $J = 7.9$ Hz, 2H), 5.62 (s, 1H), 1.15 (s, 9H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 26.7$, 35.8, 92.3, 123.5, 128.6, 128.7, 128.8, 133.4, 134.5, 138.1, 163.3, 197.1; MS (ESI): m/e (% relative intensity) = 338.1 (100) (M+H)$^+$; HR-MS: $m/e = 338.1392$, calcd. for C$_{20}$H$_{19}$NO$_4$ (M+H)$^+$ 338.1392.

2-(1-Bromo-2-oxo-2-phenylethoxy)isoindoline-1,3-dione (5i): Following the general procedure using trans-β-bromostyrene in place of styrene: white solid; yield: 61 mg (55%); mp 164–166 °C; $R_f = 0.60$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 8.27$ (d, $J = 7.3$ Hz, 2H), 7.94–7.91 (m, 2H), 7.84–7.82 (m, 2H), 7.66 (t, $J = 7.4$ Hz, 1H), 7.55 (t, $J = 7.7$ Hz, 2H), 7.19 (s, 1H); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 85.6$, 124.2, 128.7, 128.8, 130.1, 131.8, 134.6, 135.1, 162.3, 186.3; MS (ESI): m/e (% relative intensity) = 359.9 (100) (M+H)$^+$; HR-MS: $m/e = 381.9691$, calcd. for C$_{16}$H$_{10}$BrNO$_4$ (M+Na)$^+$: 381.9691.

2-[(2-Methyl-1-oxo-1-phenylpropan-2-yl)oxy]isoindoline-1,3-dione (5j): Following the general procedure using 2-methyl-1-phenylpropene in place of styrene: white solid; yield: 40 mg (42%); mp 86–89 °C; $R_f = 0.56$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 8.38$ (d, $J = 7.6$ Hz, 2H), 7.84–7.82 (m, 2H), 7.77–7.75 (m, 2H), 7.56 (t, $J = 7.4$ Hz, 1H), 7.47 (t, $J = 7.8$ Hz, 2H), 1.73 (s, 6H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 24.3$, 92.7, 123.7, 128.1, 129.0, 130.5, 132.8, 134.8, 135.0, 164.9, 198.4; MS (ESI): m/e (% relative intensity) = 310.0 (100) (M+H)$^+$; HR-MS: $m/e = 310.1079$, calcd. for C$_{18}$H$_{15}$NO$_4$ (M+H)$^+$: 310.1079.

2-[2-Oxo-2-(thiophen-2-yl)ethoxy]isoindoline-1,3-dione (5k): Following the general procedure using 2-vinylthiophene in place of styrene: faint yellow solid; yield: 56 mg (63%); mp: 150–152 °C; $R_f = 0.41$ (30% EtOAc/petroleum ether); ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 8.05$ (dd, $J = 3.8$ Hz, 1.0 Hz, 1H), 7.88–7.83 (m, 2H), 7.79–7.73 (m, 3H), 7.20 (t, $J = 4.4$ Hz, 1H), 5.29 (s, 2H); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 78.8$, 123.8, 128.5, 128.8, 133.8, 134.7, 135.1, 141.1, 163.0, 185.3; MS (ESI): m/e (% relative intensity) = 288.2 (100) (M+H)$^+$; HR-MS: $m/e = 310.0148$, calcd. for C$_{14}$H$_9$NO$_4$S (M+Na)$^+$: 310.0150.

2-[2-(4-Methoxyphenyl)-2-oxo-1-phenylethoxy]isoindoline-1,3-dione (5la): Following the general procedure using (E)-1-methoxy-4-styrylbenzene in place of styrene: colorless oil; yield: 24 mg (20%); $R_f = 0.47$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 8.00$ (d, $J = 7.8$ Hz, 2H), 7.79–7.76 (m, 3H), 7.72–7.70 (m, 2H), 7.52 (d, $J = 7.6$ Hz, 2H), 7.41 (t, $J = 7.4$ Hz, 2H), 6.86 (d, $J = 7.9$ Hz, 2H), 6.75 (s, 1H), 3.76 (s, 3H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 52.3$, 87.7, 114.4, 123.6, 123.8, 124.4, 128.6, 128.8, 129.0, 131.2, 133.6, 134.4, 160.9, 163.3, 192.8; MS (ESI): m/e (% relative intensity) = 410.1 (100) (M+Na)$^+$; HR-MS: $m/e = 410.1006$, calcd. for C$_{23}$H$_{17}$NO$_5$ (M+Na)$^+$: 410.1004.

2-[1-(4-Methoxyphenyl)-2-oxo-2-phenylethoxy]isoindoline-1,3-dione (5lb): Following the general procedure using (E)-1-methoxy-4-styrylbenzene in place of styrene: colorless oil; yield: 33 mg (27%); $R_f = 0.46$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 8.03$ (d, $J = 8.2$ Hz, 2H), 7.78–7.76 (m, 2H), 7.72–7.69 (m, 2H), 7.63–7.60 (m, 2H), 7.37–7.34 (m, 3H), 6.89 (d, $J = 8.1$ Hz, 2H), 6.71 (s, 1H), 3.83 (s, 3H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 55.5$. 88.3, 113.9, 123.6, 127.7, 128.8, 128.9, 129.4, 129.9, 131.6, 133.0, 134.5, 163.3, 163.9, 191.2; MS (ESI): m/e (% relative intensity) = 410.1 (100) (M+Na)$^+$; HR-MS: $m/e = 410.1005$, calcd. for C$_{23}$H$_{17}$NO$_5$ (M+Na)$^+$: 410.1004.

2-{2-Oxo-1-phenyl-2-[4-(trifluoromethyl)phenyl]ethoxy}-isoindoline-1,3-dione (5ma): Following the general procedure using (E)-1-styryl-4-(trifluoromethyl)benzene in place of styrene: colorless oil; yield: 34 mg (26%); $R_f = 0.60$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 8.15$ (d, $J = 8.0$ Hz, 2H), 7.79–7.76 (m, 2H), 7.74–7.72 (m, 2H), 7.69 (d, $J = 7.9$ Hz, 2H), 7.61–7.59 (m, 2H), 7.39–7.37 (m, 3H), 6.67 (s, 1H); ^{19}F NMR (564 MHz, CDCl$_3$): $\delta = -63.3$ (s, 3F); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 89.1$, 123.6, 123.7, 125.7 (q, $J = 3.3$ Hz), 128.7, 129.1, 129.2, 129.6, 130.3, 132.1, 134.4, 134.6, 163.2, 192.2; MS (ESI): m/e (% relative intensity) = 448.1 (100) (M+Na)$^+$; HR-MS: $m/e = 448.0773$, calcd. for C$_{23}$H$_{14}$F$_3$NO$_4$ (M+Na)$^+$: 448.0773.

2-{2-Oxo-2-phenyl-1-[4-(trifluoromethyl)phenyl]ethoxy}-isoindoline-1,3-dione (5mb): Following the general procedure using (E)-1-styryl-4-(trifluoromethyl)benzene in place of styrene: colorless oil; yield: 38 mg (29%); $R_f = 0.59$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 8.07$ (d, $J = 7.7$ Hz, 2H), 7.79–7.77 (m, 4H), 7.74–7.73 (m, 2H), 7.64 (d, $J = 7.8$ Hz, 2H), 7.58 (t, $J = 7.3$ Hz, 1H), 7.47 (t, $J = 7.4$ Hz, 2H), 6.77 (s, 1H); ^{19}F NMR (564 MHz, CDCl$_3$): $\delta = -62.9$ (s, 3F); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 87.8$, 123.8, 125.8 (q, $J = 3.4$ Hz), 128.7, 128.8, 129.3, 129.5, 131.8, 134.1, 134.5, 134.7, 136.7, 163.2, 192.4; MS (ESI): m/e (% relative intensity) = 448.1 (100) (M+Na)$^+$; HR-MS: $m/e = 448.0765$, calcd. for C$_{23}$H$_{14}$F$_3$NO$_4$ (M+Na)$^+$: 448.0773.

2-(2-Hydroxy-1,2,2-triphenylethoxy)isoindoline-1,3-dione (5p): Following the general procedure using triphenylethylene in place of styrene: white solid; yield: 80 mg (59%); mp 169–171 °C; $R_f = 0.46$ (30% EtOAc/petroleum ether); ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 9.03$ (brs, 1H), 7.69–7.62 (m, 4H), 7.55–7.52 (m, 2H), 7.40–7.32 (m, 5H), 7.24–7.09 (m, 8H), 6.70 (s, 1H); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 89.9$, 90.6, 123.5, 127.3, 127.6, 127.8, 127.9, 128.0, 128.7, 128.8, 129.2, 130.6, 133.1, 134.5, 139.3, 140.2, 163.8; MS (ESI): m/e (% relative intensity) = 436.1 (100) (M+H)$^+$; HR-MS: $m/e = 458.1368$, calcd. for C$_{28}$H$_{21}$NO$_4$ (M+Na)$^+$: 458.1368.

2-(2-Hydroxy-1, 2-diphenylpropoxy)isoindoline-1,3-dione (5q): Following the general procedure using trans-α-methylstilbene in place of styrene: white solid; yield: 79 mg (68%); mp 153–156 °C; $R_f = 0.48$ (30% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 10.47$ (s, 1H), 7.71 (d, $J = 13.7$ Hz, 4H), 7.34–7.24 (m, 6H), 7.16 (t, $J = 7.1$ Hz, 2H), 6.98 (d, $J = 7.1$ Hz, 2H), 5.61 (s, 1H), 1.66 (s, 3H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 20.4$, 87.1, 91.0, 123.8, 127.1, 127.5, 128.2, 128.4, 128.6, 129.1, 130.0, 134.1, 134.8, 136.7, 164.4; MS (ESI): m/e (% relative intensity) = 374.2 (100) (M+H)$^+$; $m/e = 396.1213$, calcd. for C$_{23}$H$_{19}$NO$_4$ (M+Na)$^+$: 396.1212.

2-[(1-Hydroxy-1,2-diphenylpropan-2-yl)oxy]isoindoline-1,3-dione (5q′): Following the general procedure using *trans*-α-methylstilbene in place of styrene: white solid; yield: 21 mg (18%); mp 88–91°C; $R_f = 0.47$ (30% EtOAc/petroleum ether); ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 7.87$–7.74 (m, 3H), 7.41–7.25 (m, 9H), 7.17–7.14 (m, 2H), 4.87 (s, 1H), 2.48 (brs, 1H), 1.39 (s, 3H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 24.2$, 80.9, 123.7, 125.8, 127.3, 127.7, 127.8, 127.9, 128.2, 132.6, 134.4, 139.1, 145.0, 168.0; MS (ESI): m/e (% relative intensity) = 374.0 (100) (M+H)$^+$; HR-MS: $m/e = 396.1209$, calcd. for C$_{23}$H$_{19}$NO$_4$ (M+Na)$^+$: 396.1212.

2,2′-[(2-Oxo-2-phenylethane-1,1-diyl)bis(oxy)]bis(isoindoline-1,3-dione) (5r): Following the general procedure, changing reaction temperature to 70°C and using *trans*-β-nitrostyrene in place of styrene: white solid; yield: 91 mg (66%); mp 248–251°C; $R_f = 0.23$ (30% EtOAc/petroleum ether); ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 8.50$ (d, $J = 7.6$ Hz, 2H), 7.85–7.82 (m, 4H), 7.79–7.75 (m, 4H), 7.69 (t, $J = 7.5$ Hz, 1H), 7.60 (t, $J = 7.8$ Hz, 2H), 6.08 (s, 1H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 112.3$, 124.0, 128.7, 128.8, 130.5, 132,3, 134.6, 134.8, 162.4, 187.5; MS (ESI): m/e (% relative intensity) = 443.0 (100) (M+H)$^+$; HR-MS: $m/e = 465.0699$, calcd. for C$_{24}$H$_{14}$N$_2$O$_7$ (M+Na)$^+$: 465.0699.

1-(2-oxo-2-phenylethoxy)pyrrolidine-2,5-dione (7): Following the general procedure using NHS in place of NHPI and performed in CH$_3$CN, 18 h: white solid; yield: 69 mg (96%); mp 124–126°C; $R_f = 0.30$ (50% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 7.94$ (d, $J = 7.7$ Hz, 2H), 7.62 (t, $J = 7.1$ Hz, 1H), 7.49 (t, $J = 7.3$ Hz, 2H), 5.38 (s, 2H), 2.75 (s, 4H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 25.5$, 77.0, 128.2, 128.9, 134.17, 134.21, 170.7, 192.1; HR-MS (ESI): $m/e = 256.0585$, calcd. for C$_{12}$H$_{11}$NO$_4$ (M+Na)$^+$: 256.0586.

4-{2-[(2,5-Dioxopyrrolidin-1-yl)oxy]acetyl}benzonitrile (8): Following the general procedure using NHS in place of NHPI, 4-cyanostyrene in place of styrene and performed in CH$_3$CN, 15 h: white solid; yield: 74 mg (92%); mp 156–158°C; $R_f = 0.28$ (50% EtOAc/petroleum ether); ^{1}H NMR (600 MHz, DMSO): $\delta = 8.08$ (d, $J = 7.9$ Hz, 2H), 8.04 (d, $J = 7.8$ Hz, 2H), 5.41 (s, 2H), 2.62 (s, 4H); ^{13}C NMR (150 MHz, DMSO): $\delta = 25.4$, 77.6, 115.6, 118.0, 128.7, 132.8, 137.6, 171.4, 192.4; MS (ESI): m/e (% relative intensity) = 281.0 (100) (M+Na)$^+$; HR-MS: $m/e = 281.0538$, calcd. for C$_{13}$H$_{10}$N$_2$O$_4$ (M+Na)$^+$: 281.0538.

2-[(1H-Benzo[d][1,2,3]triazol-1-yl)oxy]-1-phenylethanone (10): Following the general procedure using HOBt in place of NHPI and reducing the amount of styrene to 1.2 equiv., 24 h: white solid; yield: 79 mg (100%); mp 94–96°C; ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 7.98$ (d, $J = 8.4$ Hz, 1H), 7.94 (d, $J = 8.3$ Hz, 1H), 7.90 (d, $J = 7.5$ Hz, 2H), 7.62 (, $J = 7.2$ Hz, 1H), 7.56 (t, $J = 7.4$ Hz, 1H), 7.49 (t, $J = 7.7$ Hz, 2H), 7.39 (t, $J = 7.6$ Hz, 1H), 5.95 (s, 2H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 80.0$, 110.4, 119.9, 124.8, 127.8, 128.3, 129.1, 133.7, 134.5, 143.5, 191.7.

2-[(1H-Benzo[d][1,2,3]triazol-1-yl)oxy]-1-phenylpropan-1-one (11): Following the general procedure using HOBt in place of NHPI and using (Z/E)-β-methylstyrene (1.2 equiv.) in place of styrene, 5 h: colorless oil; yield: 75 mg (90%); ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 7.96$ (d, $J = 7.3$ Hz, 3H), 7.84 (d, $J = 8.3$ Hz, 1H), 7.59 (t, $J = 7.1$ Hz, 1H), 7.53 (t, $J = 7.4$ Hz, 1H), 7.47 (t, $J = 7.6$ Hz, 2H), 7.36 (t, $J = 7.6$ Hz, 1H), 6.38 (q, $J = 6.9$ Hz, 1H), 1.79 (d, $J = 6.8$ Hz, 3H); ^{13}C NMR

(150 MHz, CDCl$_3$): $\delta = 17.1$, 85.4, 110.2, 119.8, 124.8, 128.2, 128.3, 128.6, 129.0, 134.1, 134.3, 143.3, 195.5.

Procedure for Cleavage of the O−C Bond

Bu$_3$SnH (34.5 μL, 0.13 mmol) and AIBN (2.6 mg, 0.017 mmol) in degassed benzene were slowly added to a solution of **3a** (30 mg, 0.11 mmol) in degassed benzene at reflux. The reaction mixture was stirred for an additional 3 h at reflux. The resulting solution was allowed to cool to room temperature, then it was extracted with EtOAc and washed with brine. The crude product was purified by flash column chromatography to afford **12** (yield: 9 mg, 70%; brsm 99%) together with **3a** (yield: 9 mg) recovered. **12**: colorless oil; ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 7.97$ (d, $J = 7.8$ Hz, 2H), 7.57 (t, $J = 7.4$ Hz, 1H), 7.47 (t, $J = 7.8$ Hz, 2H), 2.62 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 26.6$, 128.3, 128.6, 133.1, 137.1, 198.2.

Bu$_3$SnH (22 μL, 0.083 mmol) and AIBN (1.7 mg, 0.010 mmol) in degassed benzene were slowly added to a solution of **5f** (24 mg, 0.069 mmol) in degassed benzene at reflux. The reaction mixture was stirred for an additional 3 h at reflux. The resulting solution was allowed to cool to room temperature, then extracted with EtOAc and washed with brine. The crude product was purified by flash column chromatography to afford **13** as a colorless oil; yield: (13 mg, 99%); $R_f = 0.52$ (5% EtOAc/petroleum ether); ^{1}H NMR (400 MHz, CDCl$_3$): $\delta = 7.96$ (d, $J = 7.3$ Hz, 2H), 7.56 (t, $J = 7.3$ Hz, 1H), 7.46 (t, $J = 7.7$ Hz, 2H), 5.87–5.76 (m, 1H), 5.04–4.94 (m, 2H), 2.98 (t, $J = 7.3$ Hz, 2H), 2.11 (q, $J = 7.2$ Hz, 2H), 1.77 (p, $J = 7.7$ Hz, 2H), 1.49 (p, $J = 7.5$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl$_3$): $\delta = 23.8$, 28.6, 33.6, 38.4, 114.7, 128.1, 128.6, 132.9, 137.0, 138.6, 200.4; MS (ESI): m/e (% relative intensity) = 189.1 (100) (M+H)$^+$; HR-MS: $m/e = 189.1279$, calcd. for C$_{13}$H$_{16}$O (M+H)$^+$: 189.1279.

Hydrochloric acid (3N, 1.5 mL) was added to a solution of **10** (29 mg, 0.11 mmol) in THF (1.5 mL). After being stirred at 80°C for 24 h, the resulting solution was allowed to cool to room temperature, then extracted with EtOAc, and washed with brine. The crude product was purified by flash column chromatography to afford **14** as a yellow oil; yield: 16 mg (90%). ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 7.97$ (d, $J = 7.6$ Hz, 2H), 7.63 (t, $J = 7.3$ Hz, 1H), 7.51 (t, $J = 7.5$ Hz, 2H), 4.74 (s, 2H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 46.1$, 128.5, 128.9, 134.1, 134.2, 191.1.

Hydrobromic acid (3N, 1.5 mL) was added to a solution of **10** (22 mg, 0.087 mmol) in THF (1.5 mL). After being stirred at 80°C for 1 h, the resulting solution was allowed to cool to room temperature, then extracted with EtOAc, and washed with brine. The crude product was purified by flash column chromatography to afford **15** as a yellow oil; yield: 16 mg (100%). ^{1}H NMR (600 MHz, CDCl$_3$): $\delta = 7.99$ (d, $J = 7.7$ Hz, 2H), 7.62 (t, $J = 7.3$ Hz, 1H), 7.50 (t, $J = 7.6$ Hz, 2H), 4.47 (s, 2H); ^{13}C NMR (150 MHz, CDCl$_3$): $\delta = 31.0$, 128.9, 129.0, 133.9, 134.9, 191.3.

Labeling Studies

An oven-dried reaction tube was charged with *N*-hydroxyphthalimide (0.1 mmol), styrene (0.25 mmol), FeCl$_3$ (0.01 mmol), anhydrous CH$_3$CN (720 μL) and H$_2$^{18}O (80 μL). A balloon charged with O$_2$ was added and the tube was evacuated and backfilled with O$_2$ thrice. The reaction

was performed at room temperature for 2 days. The mixture was poured into water and extracted with ethyl acetate. The combined organic layers were dried over Na_2SO_4, filtered and then concentrated under reduced pressure. The product was obtained *via* flash column chromatography (gradient eluent: 15%-20% ethyl acetate in hexanes) and analyzed *via* MS and HR-MS. Both types of the corresponding peaks were found in the mass spectra.

[18]O **product (16):** MS (ESI): *m/e* (% relative intensity) = 306.1 (100) (M + Na)[+]; HR-MS: *m/e* = 306.0644, calcd. for $C_{16}H_{11}NO_3{}^{18}O$ (M + Na)[+]: 306.0637.

[16]O **product (3a):** MS (ESI): *m/e* (% relative intensity) = 304.1 (100) (M + Na)[+]; HR-MS: *m/e* = 304.0582, calcd. for $C_{16}H_{11}NO_4$ (M + Na)[+]: 304.0580.

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References

[1] a) H. Egami, M. Sodeoka, *Angew. Chem.* **2014**, *126*, 8434–8449; *Angew. Chem. Int. Ed.* **2014**, *53*, 8294–8308; b) S. R. Chemler, M. T. Bovino, *ACS Catal.* **2013**, *3*, 1076–1091; c) K. Muñiz, C. Martínez, *J. Org. Chem.* **2013**, *78*, 2168–2174; d) S.-X. Huang, K.-L. Ding, *Angew. Chem.* **2011**, *123*, 7878–7880; *Angew. Chem. Int. Ed.* **2011**, *50*, 7734–7736; e) C. J. R. Bataille, T. J. Donohoe, *Chem. Soc. Rev.* **2011**, *40*, 114–128; f) A. Minatti, K. Muñiz, *Chem. Soc. Rev.* **2007**, *36*, 1142–1152; g) D. J. Chen, C. Timmons, H. X. Wei, G. G. Li, *J. Org. Chem.* **2003**, *68*, 5742–5745; h) H. X. Wei, S. Siruta, G. G. Li, *Tetrahedron Lett.* **2002**, *43*, 3809–3812; i) H. C. Kolb, M. S. VanNieuwenhze, K. B. Sharpless, *Chem. Rev.* **1994**, *94*, 2483–2574.

[2] a) H. C. Kolb, M. S. VanNieuwenhze, K. B. Sharpless, *Chem. Rev.* **1994**, *94*, 2483–2574; b) A. Wang, H. Jiang, H. Chen, *J. Am. Chem. Soc.* **2009**, *131*, 3846–3847; c) Y. Li, D. Song, V. M. Dong, *J. Am. Chem. Soc.* **2008**, *130*, 2962–2964; d) Y. Zhang, M. S. Sigman, *J. Am. Chem. Soc.* **2007**, *129*, 3076–3077; e) J. Seayad, A. M. Seayad, C. L. L. Chai, *Org. Lett.* **2010**, *12*, 1412–1415; f) T. W.-S. Chow, E. L.-M. Wong, Z. Guo, Y. Liu, J.-S. Huang, C.-M. Che, *J. Am. Chem. Soc.* **2010**, *132*, 13229–13239. For a recent metal-free process using stoichiometric peroxide as the oxidant, see: g) J. C. Griffith, K. M. Jones, S. Picon, M. J. Rawling, B. M. Kariuki, M. Campbell, N. C. O. Tomkinson, *J. Am. Chem. Soc.* **2010**, *132*, 14409–14411; h) L. Emmanuvel, T. M. A. Shaikh, A. Sudalai, *Org. Lett.* **2005**, *7*, 5071–5073.

[3] For selected recent reviews on iron-catalyzed reactions, see: a) I. Bauer, H. J. Knölker, *Chem. Rev.* **2015**, *115*, 3170–3387; b) C. Bolm, J. Legros, J. Le Paih, L. Zani, *Chem. Rev.* **2004**, *104*, 6217–6254; c) E. B. Bauer, *Curr. Org. Chem.* **2008**, *12*, 1341–1369; d) C. Sun, B. Li, Z.

Shi, *Chem. Rev.* **2011**, *111*, 1293–1314; e) *Iron Catalysis: Fundamentals and Applications*, in: *Topics in Organometallic Chemistry*, (Ed.: B. Plietker), Springer Verlag, Berlin, **2011**, Vol. 33. For recent examples of iron-catalyzed difunctionalization, see: f) T. Taniguchi, Y. Sugiura, H. Zaimoku, H. Ishibashi, *Angew. Chem.* **2010**, *122*, 10352–10355; *Angew. Chem. Int. Ed.* **2010**, *49*, 10154–10157; g) Y. Su, X. Sun, G. Wu, N. Jiao, *Angew. Chem.* **2013**, *125*, 9990–9994; *Angew. Chem. Int. Ed.* **2013**, *52*, 9808–9812; h) W. Wei, J.-X. Ji, *Angew. Chem.* **2011**, *123*, 9263–9265; *Angew. Chem. Int. Ed.* **2011**, *50*, 9097–9099.

[4] For recent examples of iron-catalyzed epoxidations, see: a) S. Taktak, W. Ye, A. M. Herrera, E. V. Rybak-Akimova, *Inorg. Chem.* **2007**, *46*, 2929–2942; b) M. R. Bukowski, P. Comba, A. Lienke, C. Limberg, C. Lopez de Laorden, R. Mas-Ballesté, M. Merz, L. Que Jr, *Angew. Chem.* **2006**, *118*, 3524–3528; *Angew. Chem. Int. Ed.* **2006**, *45*, 3446–3449; c) G. Dubois, A. Murphy, T. D. P. Stack, *Org. Lett.* **2003**, *5*, 2469–2472; d) K. Chen, M. Costas, J. Kim, A. T. Tipton, L. Que Jr, *J. Am. Chem. Soc.* **2002**, *124*, 3026–3035; e) M. C. White, A. G. Doyle, E. N. Jacobsen, *J. Am. Chem. Soc.* **2001**, *123*, 7194–7195; f) B. Bitterlich, K. Schröder, M. K. Tse, M. Bellerfor, *Eur. J. Org. Chem.* **2008**, *29*, 4867–4870.

[5] a) A. Carboni, G. Dagousset, E. Magnier, G. Masson, *Chem. Commun.* **2014**, *50*, 14197–14200; b) F. Xu, L. Zhu, S.-B. Zhu, X.-M. Yan, H.-C. Xu, *Chem. Eur. J.* **2014**, *20*, 12740–12746; c) W.-Q. Kong, E. Merino, C. Nevado, *Angew. Chem.* **2014**, *126*, 5178–5182; *Angew. Chem. Int. Ed.* **2014**, *53*, 5078–5082; d) S. H. Oh, Y. R. Malpani, N. Ha, Y.-S. Jung, S. B. Han, *Org. Lett.* **2014**, *16*, 1310–1313; e) Q.-Q. Lu, C. Liu, Z.-Y. Huang, Y.-Y. Ma, J. Zhang, A.-W. Lei, *Chem. Commun.* **2014**, *50*, 14101–14104; f) F. Wang, D.-H. Wang, X. Mu, P.-H. Chen, G.-S. Liu, *J. Am. Chem. Soc.* **2014**, *136*, 10202–10205; g) A. Deb, S. Manna, A. Modak, T. Patra, S. Maity, D. Maiti, *Angew. Chem.* **2013**, *125*, 9929–9932; *Angew. Chem. Int. Ed.* **2013**, *52*, 9747–9750; h) Y.-J. Su, X. Sun, G.-L. Wu, N. Jiao, *Angew. Chem.* **2013**, *125*, 9990–9994; *Angew. Chem. Int. Ed.* **2013**, *52*, 9808–9812; i) C.-W. Zhang, Z.-D. Li, L. Zhu, L.-M. Yu, Z.-T. Wang, C.-Z. Li, *J. Am. Chem. Soc.* **2013**, *135*, 14082–14085; j) M.-B. Zhou, C.-Y. Wang, R.-J. Song, Y. Liu, W.-T. Wei, J.-H. Li, *Chem. Commun.* **2013**, *49*, 10817–10819; k) R. Zhu, S. L. Buchwald, *Angew. Chem.* **2013**, *125*, 12887–12890; *Angew. Chem. Int. Ed.* **2013**, *52*, 12655–12658; l) X.-Y. Duan, X.-L. Yang, R. Fang, X.-X. Peng, W. Yu, B. Han, *J. Org. Chem.* **2013**, *78*, 10692–10704.

[6] a) B. C. Giglio, V. A. Schmidt, E. J. Alexanian, *J. Am. Chem. Soc.* **2011**, *133*, 13320–13322; b) V. A. Schmidt, E. J. Alexanian, *Angew. Chem.* **2010**, *122*, 4593–4596; *Angew. Chem. Int. Ed.* **2010**, *49*, 4491–4494; c) V. A. Schmidt, E. J. Alexanian, *J. Am. Chem. Soc.* **2011**, *133*, 11402–11405; d) R. N. Reddi, P. K. Prasad, A. Sudalai, *Org. Lett.* **2014**, *16*, 5674–5677.

[7] a) O. Shigeko, H. Tomomi, T. Keiichi, *J. Chem. Soc. Perkin Trans. 2* **1989**, 951; b) B. Raghunath, S. Dinabandhu, P. Tharmalingam, *Org. Lett.* **2015**, *17*, 2010–2013; c) A. A. Andia, M. R. Miner, K. A. Woerpel, *Org. Lett.* **2015**, *17*, 2704–2707; d) X. F. Xia, S. L. Zhu,

Z. Gu, H. J. Wang, W. Li, X. Liu, Y. M. Liang, *J. Org. Chem.* **2015**, *80*, 5572–5580.

[8] L.-W. Liu, Z.-Z. Wang, H.-H. Zhang, Wan.-S. Wang, J.-Z. Zhang, Y. Tang, *Chem. Commun.* **2015**, *51*, 9531–9534.

[9] R. Lin, F. Chen, N. Jiao, *Org. Lett.* **2012**, *14*, 4158–4161.

[10] a) C.-L. Sun, B.-J. Li, Z.-J. Shi, *Chem. Rev.* **2011**, *111*, 1293–1314; b) S.-M. Yiu, Z.-B. Wu, C.-K. Mak, T.-C. Lau, *J. Am. Chem. Soc.* **2004**, *126*, 14921–14929; c) Y. Sawama, M. Masuda, S. Asai, R. Goto, S. Nagata, S. Nishimura, Y. Monguchi, H. Sajiki, *Org. Lett.* **2015**, *17*, 434–437; d) Z.-P. Zhan, X.-B. Cai, S.-P. Wang, J.-L. Yu, H.-J. Liu, Y.-Y. Cui, *J. Org. Chem.* **2007**, *72*, 9838–9841; e) I. Bauer, H. J. Knölker, *Chem. Rev.* **2015**, *115*, 3170–3387.

[11] For examples, see: a) J. T. Liu, Y. J. Jiang, Y. K. Shih, S. R. Hu, C. M. Chu, C. F. Yao, *J. Org. Chem.* **2001**, *66*, 6021–6028; b) X. J. Quan, Z. H. Ren, Y. Y. Wang, Z. H. Guan, *Org. Lett.* **2014**, *16*, 5728–5731; c) Y. J. Jang, M. C. Yan, Y. F. Lin, C. F. Yao, *J. Org. Chem.* **2004**, *69*, 3961–3963.

[12] a) F. Recupero, C. Punta, *Chem. Rev.* **2007**, *107*, 3800–3842; b) J. M. Lee, E. J. Park, S. H. Cho, S. Chang, *J. Am. Chem. Soc.* **2008**, *130*, 7824–7825; c) B. Tan, N. Toda, C. F. Barbas III, *Angew. Chem.* **2012**, *124*, 12706–12709; *Angew. Chem. Int. Ed.* **2012**, *51*, 12538–12541; d) X.-F. Xia, Z. Gu, W. Liu, H. Wang, Y. Xia, H. Gao, X. Liu, Y.-M. Liang, *J. Org. Chem.* **2015**, *80*, 290–295.