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Transition-Metal-Free Synthesis of Carbonyl-Containing Oxindoles from *N*-Arylacrylamides and α-Diketones via TBHP- or Oxone-Mediated Oxidative Cleavage of C(sp^2)−C(sp^2) Bonds

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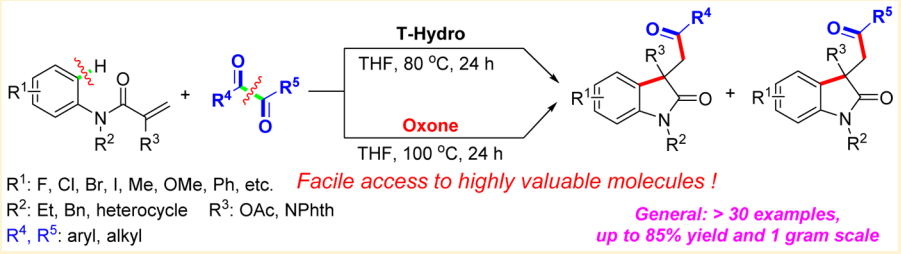
Supporting Information



ABSTRACT: Carbonyl-containing oxindoles can be prepared from *N*-arylacrylamides and α-diketones by TBHP- or oxone ($KHSO_5$)-mediated C(sp^2)−C(sp^2) bond cleavage and new C(sp^2)−C(sp^3) bond formation. This methodology is characterized by its simple and transition-metal-free conditions and good functional group compatibility utilizing inexpensive and readily available reagents, thus providing a practical and efficient approach to an important class of 3-(2-oxoethyl)indolin-2-ones which are highly valued synthetic intermediates of biologically active molecules. In this transformation, alkylcarbonyl-containing oxindoles were obtained in majority when *N*-arylacrylamides reacted with asymmetric aliphatic/aromatic α-diketones. On the basis of the preliminary experiments, a plausible mechanism of this transformation is disclosed.

INTRODUCTION

Carbon−carbon bond cleavage has gained considerable momentum over the past decade, holding great promise for constructing useful structural units from simple molecular skeletons. In this field, transition-metal-catalyzed cleavages of C═C double bonds,[1] C≡C triple bonds,[2] aryl-cyano C(sp^2)−C(sp) bonds,[3] and secondary/tertiary alcohol C(sp^3)−C bonds[4] have been significantly developed. These discoveries present effective strategies for the chemoselective construction of the target molecules which take a privileged position in the fields of pharmaceuticals, biochemistry, and materials science. Despite formidable success, however, the selective C−C bond cleavage of ketones is a long-standing challenge. By using a copper/O_2 catalytic oxidation system, Bi and Liu et al. pioneeringly disclosed a chemoselective oxidative C(CO)−C(methyl) bond cleavage of methyl ketones for accessing aldehydes.[5] Since then, copper-catalyzed aerobic oxidative processes for activating inert ketones have shown considerable promise in this area.[6] Our group also disclosed a copper-catalyzed aerobic oxidative C(CO)−C(alkyl) bond cleavage strategy for the conversion of ketones to nitriles.[7] As part of our continuing interest in C−C bond cleavage and transformation,[2a,7,8] herein, we present the discovery of a transition-metal-free oxidative C(sp^2)−C(sp^2) bond cleavage strategy to construct carbonyl-containing oxindoles from *N*-arylacrylamides and readily available α-diketones (Scheme 1).

To the best of our knowledge, carbon-acylation using α-diketones as acyl precursors through a C(sp^2)−C(sp^2) bond cleavage mode, particularly from easily available substrates to give high-value compounds, have remained relatively underdeveloped.[9]

Oxindoles are ubiquitous heterocyclic motifs that are widely present in many naturally occurring and pharmaceutical molecules.[10] Members of the oxindole family have wide applications in medicinal chemistry owning to their remarkable biological activities, such as anticancer,[11] antitumoral,[12] anti-inflammatory,[13] antimicrobial,[14] and antiplasmodium falciparum.[15] Specially, carbonyl-containing oxindoles, including 3-(2-oxoethyl)indolin-2-ones, are extremely attractive as intermediates in the synthesis of indole alkaloids such as chimonanthine and folicanthine.[16] Thus, the development of an efficient, economical, and environmentally benign approach to access oxindoles, and in particular for carbonyl-containing oxindoles from easily available chemical materials, would be highly desirable.[17,18] In 2013, Li et al. pioneered the oxidative coupling of alkenes with aldehyde C(sp^2)−H bonds and aryl C(sp^2)−H bonds to access carbonyl-containing oxindoles using anhydrous TBHP at 105 °C.[19] Later on, transition-metal-catalyzed processes such as oxidative cascade coupling of activated

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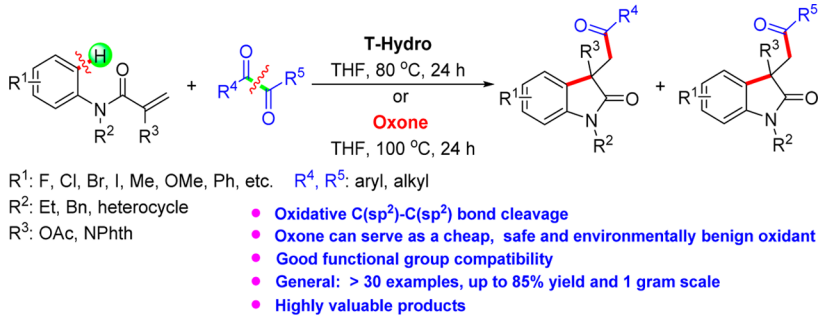
Scheme 1. Oxidative Cleavage of C(sp^2)−C(sp^2) Bonds in α-Diketones Leading to Carbonyl-Containing Oxindoles

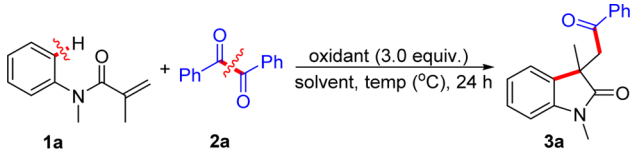


alkenes with aryl aldehydes,[20] decarboxylative acylarylation of activated alkenes with α-oxocarboxylic acids,[21] and oxidative 1,2-carboacylation of activated alkenes with alcohols[22] have also been proposed as complementary methods for the preparation carbonyl-containing oxindoles. Nevertheless, these well-established approaches suffered from one or more limitations including limited functional group tolerance, the use of expensive radical initiator or starting material (e.g., anhydrous TBHP and α-oxocarboxylic acids), and/or precious or toxic metal reagents, which may limit their applicability in the areas of pharmaceutical industry, etc. Recently, Xia et al. disclosed a very attractive access to carbonyl-containing oxindoles through UV-light-mediated difunctionalization of alkenes using benzoin as the benzoyl precursor;[23] however, the requirement for ultraviolet light irradiation and excessive solvent (50 mL of solvent for 0.3 mmol of substrate) makes this reaction operationally and economically unfavorable. On the basis of these concerns as well as our ongoing efforts in the development of green and sustainable methods toward oxindoles,[24] we report our recent progress in this field (Scheme 1). The significance of the present finding is three-fold: (1) This work demonstrates the first construction of carbonyl-containing oxindoles via oxidative cleavage mode of C(sp^2)−C(sp^2) bond mediated by TBHP or oxone ($KHSO_5$). (2) This methodology is characterized by its simple and transition-metal-free conditions and good functional group compatibility utilizing inexpensive and readily available α-diketones as acyl precursors, thus becoming a powerful alternative for accessing these highly valuable compounds in an expeditious manner. (3) By using oxone ($KHSO_5$) as a safe and environmentally benign oxidant, the transformation was successfully conducted on a gram scale (65% yield), which makes this unprecedented protocol very attractive for potential pharmaceutical and industrial applications.

RESULTS AND DISCUSSION

We initiated our investigation by reacting *N*-arylacrylamide (**1a**) with α-diphenyl ketone (**2a**) as the model reaction, and the effects of various temperatures, solvents, and oxidants were systematically examined (Table 1). An initial experiment using 3.0 equiv of T-Hydro (70% *tert*-butyl hydroperoxide in water) as the oxidant, THF as the solvent, and at 100 °C under a N_2 atmosphere for 24 h led to the formation of the expected product **3a** in 59% yield (entry 1). Control experiments without TBHP showed no formation of the desired product **3a**, pointing at the decisive role of oxidant in this transformation (entry 2). To our delight, the best yield (78%) was achieved when decreasing the reaction temperature to 80 °C (entry 3). In comparison, when anhydrous TBHP (5 M in decane) was used as the oxidant, a slightly decreased yield (75%) of **3a** was obtained (entry 4). With continued use of T-Hydro as the oxidant, other solvents were tested, including CH_3CN, DMF, DMSO, DCE, dioxane, and EtOAc, all which had a deleterious effect on reactivity (entries 5−10). In light of these results, the effect of various organic oxidants such as di-*tert*-butyl peroxide (DTBP), dicumyl peroxide (DCP), *tert*-butyl peroxybenzoate (TBPB), benzoyl peroxide (BPO), and *o*-idoxybenzoic acid (IBX) was examined. The results showed T-Hydro to be the ideal choice for this transformation (entry 3 vs entries 11−15).

Table 1. Optimization of Reaction Conditions[a]



entry	oxidant	solvent	temp (°C)	yield (%)[b]
1[c]	TBHP	THF	100	59
2	none	THF	100	0
3[c]	TBHP	THF	80	78
4[d]	TBHP	THF	80	75
5[c]	TBHP	CH_3CN	80	0
6[c]	TBHP	DMF	80	23
7[c]	TBHP	DMSO	80	trace
8[c]	TBHP	DCE	80	trace
9[c]	TBHP	dioxane	80	35
10[c]	TBHP	EtOAc	80	trace
11	DTBP	THF	80	20
12	DCP	THF	80	21
13	TBPB	THF	80	16
14	BPO	THF	80	30
15	IBX	THF	80	trace

[a]Reaction conditions: *N*-arylacrylamide (**1a**, 0.3 mmol), α-diphenyl ketone (**2a**, 0.45 mmol), oxidant (0.9 mmol), solvent (2.0 mL), N_2, 24 h. [b]Yield of isolated product. [c]T-Hydro. [d]TBHP (anhydrous, 5 M in decane).

Encouraged by these findings, we turned our attention to explore the scope of *N*-arylacrylamides (**1**) with **2a** (Table 2). The effect of various substitution patterns on the *N*-aryl moiety was first investigated. The substrates with halo-substituents (F, Cl, Br, and I) were well tolerated under the optimized conditions, leading to the corresponding carbonyl-containing oxindoles in yields ranging from 72% to 80% (**3b**−**3e**), which enable further functionalization or modification of these molecules. However, strong electron-withdrawing substituents, such as a NO_2 group on the *N*-aryl moiety, did not result in any product (**3f**). To our delight, electron-donating substituents,

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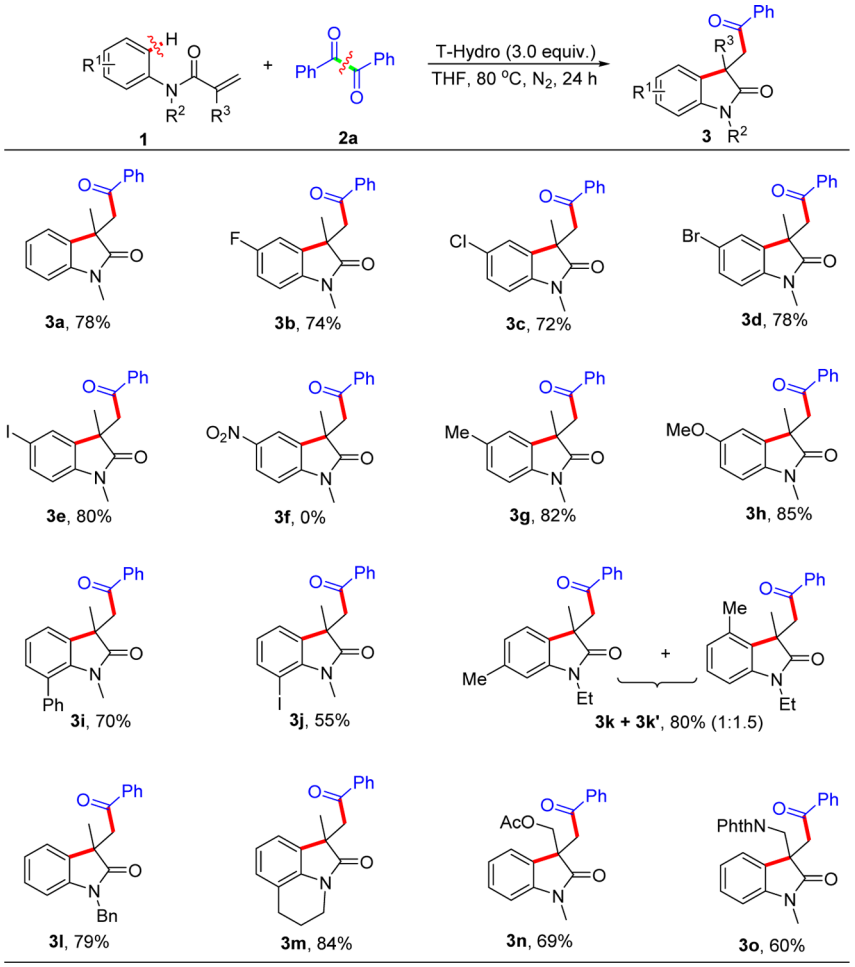
Table 2. Synthesis of Carbonyl-Containing Oxindoles: Scope of *N*-Arylacrylamides[a,b]



[a]Reaction conditions: *N*-arylacrylamides (**1**, 0.3 mmol), α-diphenyl ketone (**2a**, 0.45 mmol), T-Hydro (0.9 mmol), and THF (2.0 mL) at 80 °C under a N_2 atmosphere for 24 h. [b]Isolated yields.

such as Me, and OMe groups on the aryl ring were well tolerated, providing the corresponding products in good to high yields (82% and 85%, **3g** and **3h**). Interestingly, the sterically congested *ortho*-substituted substrates were also reacted satisfactorily to deliver the desired oxindole products **3i** and **3j** in 70% and 55% yield, respectively. Next, we focused on *N*-arylacrylamides bearing different substituents at the N atom (R^2). As a special example, the *N*-ethyl-substituted substrate, which bears a *meta* methyl group on the aryl ring, could also serve as a suitable reaction partner in this protocol and afforded a mixture of two regioisomers in 80% yield (**3k**/**3k′** in a ratio of 1:1.5). Moreover, an *N*-benzyl derivative and a tetrahydroquinoline derivative were also compatible with the reaction conditions, affording the corresponding oxindoles **3l** and **3m** in 79% and 84% yield, respectively. Finally, the substituent effect at the 2-position (R^3) of the acrylamide moiety was investigated. Gratifyingly, both CH_2OAc and 1,3-dioxoisoindolin-2-yl groups were tolerated in this reaction (products **3n** and **3o**).

Furthermore, the reactivity of different asymmetric α-diketones (**2**) was tested with **1a** as the reaction partner, and the results are given in Table 3. It was found that asymmetric aromatic/aliphatic α-diketones, such as 1-phenylpropane-1,2-dione (**2b**) and 1-phenylbutane-1,2-dione (**2c**), reacted smoothly with **1a** to generate the corresponding products in good total yields (entries 1 and 2). Interestingly, a series of asymmetric aromatic benzil derivatives (**2d**–**2h**) with both electron-withdrawing and electron-donating groups on the aryl rings showed the selective formation of carbonyl-containing oxindoles with ratios ranging from 43:25 to 51:19 (entries 3–7). Compared to aromatic/aromatic benzil derivatives, aromatic/aliphatic ones gave the alkylcarbonyl-containing products in majority; the reason may be due to that the reactivity of arylcarbonyl reacted with a free radical is superior to that of alkylcarbonyl with the same radical.[25] These results encouraged us to further investigate the reactivity of dialkyl substituted α-diketones. As expected, both symmetrical and asymmetric aliphatic/aliphatic α-diketones, such as 2,3-butanedione (**2i**), and 2,3-pentanedione (**2j**) were performed well in this transformation (for details, see the Supporting Information).

To determine whether the selective acylarylation can take place between two α-diketones with *N*-arylacrylamides, a competition experiment was designed (Scheme 2). An equimolar mixture of symmetrical α-diketones **2a** and **2k** was submitted to the standard conditions, producing a 55:21 ratio of both carbonyl-containing oxindoles **3a** and **3v**. This suggests that the introduction of a functional group on the aryl ring of the α-diketone molecules affects the selectivity of this transformation.

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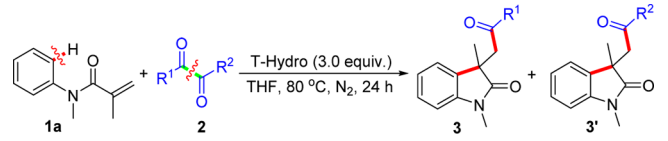
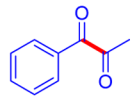
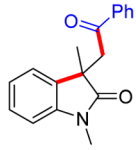
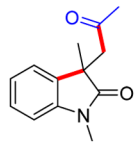
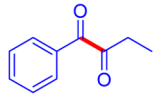
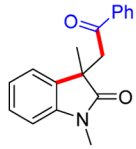
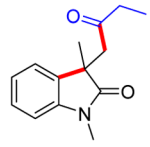
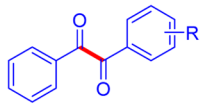
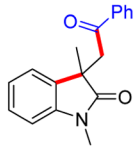
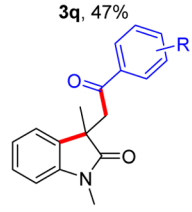
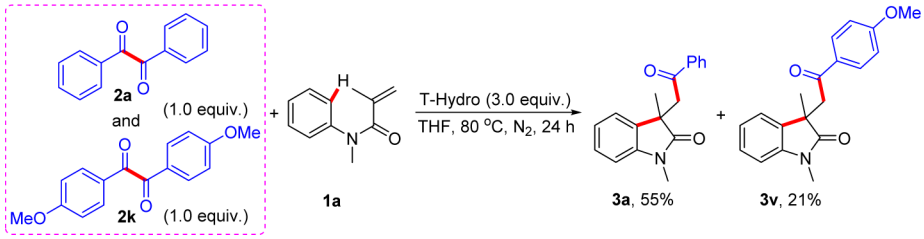
Table 3. TBHP-Mediated Oxidative Cleavage of C(sp^2)−C(sp^2) Bonds in Asymmetric α-Diketones Leading to Carbonyl-Containing Oxindoles[a,b]



entry	substrate (**2**)	**3**, yield (%)[b]	**3'**, yield (%)[b]
1	 **2b**	 **3a**, 26%	 **3p**, 53%
2	 **2c**	 **3a**, 30%	 **3q**, 47%
3	 R = *p*-F, **2d**	 **3a**, 43%	 R = *p*-F, **3r**, 25%
4	R = *o*-F, **2e**	**3a**, 40%	R = *o*-F, **3s**, 20%
5	R = *p*-CN, **2f**	**3a**, 58%	R = *p*-CN, **3t**, 16%
6	R = *p*-Me, **2g**	**3a**, 45%	R = *p*-Me, **3u**, 33%
7	R = *p*-OMe, **2h**	**3a**, 51%	R = *p*-OMe, **3v**, 19%

[a]Reaction conditions: *N*-arylacrylamide (**1a**, 0.3 mmol), α-diketones (**2**, 0.45 mmol), T-Hydro (0.9 mmol), and THF (2.0 mL) at 80 °C under a N_2 atmosphere for 24 h. [b]Isolated yields.

Scheme 2. Competition Experiment



In view of the potential applications of these molecules in the field of pharmaceutical industry,[16] we next considered the possibility of achieving this transformation by using the safe inorganic oxidant. Obviously, inexpensive and environmentally benign persulfates or monopersulfates are more attractive. To realize such an organoperoxide-free protocol, we tested various reaction parameters for the conversion of model substrates **1a** and **2a** into carbonyl-containing oxindole **3a** (Table 4). Unfortunately, the combination of $K_2S_2O_8$ and $(NH_4)_2S_2O_8$ with different solvents, such as CH_3CN-H_2O, CH_3CN, or THF, turned out not to be successful (entries 1−4). To our delight, the desired transformation was successfully achieved with oxone ($KHSO_5$), yielding the corresponding product **3a** in 59% yield (entry 5). Interestingly, the yield of **3a** was further improved to 71% when increasing the temperature to 100 °C (entry 6), while decreasing the temperature lead to a decrease in reaction efficiency (entries 7 and 8). Screening on the amount of oxone revealed that 2.5 equiv of oxone was perfect (entry 6 vs entries 9 and 10). Among the effects of the solvents examined, it was found that THF is the best choice (entry 6 vs entries 11−17). In addition, a 1 g (5.7 mmol) scale reaction of *N*-arylacrylamide **1a** is successfully performed with α-diphenyl ketone **2a**, giving **3a** in good yield (entry 18).

By using this optimized organoperoxide-free protocol, we converted a variety of structurally different substrates selectively into the respective carbonyl-containing oxindoles. As listed in Table 5, *N*-arylacrylamides with both electron-withdrawing and electron-donating groups on the aryl ring showed better reactivity (products **3b−e** and **3h**). Besides, *N*-benzyl and tetrahydroquinoline derivatives also showed reactivity in this reaction with synthetically useful yields (products **3l** and **3m**). Furthermore, different asymmetric α-diketones such as 1-

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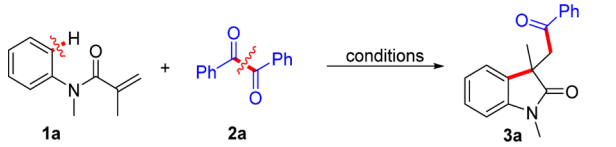
Table 4. Evaluation of the Reaction Conditions for the Synthesis of Carbonyl-Containing Oxindoles from *N*-Arylacrylamides and α-Diketones Using the Safe Oxidant[a]



1a 2a 3a

entry	oxidant (equiv)	solvent	T (°C)	yield[b] (%)
1[c]	$K_2S_2O_8$ (2.5)	CH_3CN-H_2O	80	trace
2[c]	$(NH_4)_2S_2O_8$ (2.5)	CH_3CN-H_2O	80	0
3	$K_2S_2O_8$ (2.5)	CH_3CN	80	trace
4	$K_2S_2O_8$ (2.5)	THF	80	trace
5	oxone (2.5)	THF	80	59
6	oxone (2.5)	THF	100	71
7	oxone (2.5)	THF	60	29
8	oxone (2.5)	THF	30	trace
9	oxone (3.0)	THF	100	68
10	oxone (2.0)	THF	100	64
11	oxone (2.5)	CH_3CN	100	15
12[c]	oxone (2.5)	CH_3CN-H_2O	100	trace
13	oxone (2.5)	DCE	100	trace
14	oxone (2.5)	DMF	100	trace
15	oxone (2.5)	dioxane	100	40
16	oxone (2.5)	DMSO	100	0
17	oxone (2.5)	toluene	100	trace
18[d]	oxone (2.5)	THF	100	65

[a]Reaction conditions: *N*-arylacrylamide (**1a**, 0.3 mmol), α-diphenyl ketone (**2a**, 0.45 mmol), oxidant (2.5 equiv), solvent (3.0 mL), N_2, 24 h. [b]Yield of isolated product. [c]CH_3CN-H_2O (v:v, 1:1). [d]**1a** (1 g, 5.7 mmol) and solvent (15 mL) for 36 h.

phenylpropane-1,2-dione **2b** and 1-(4-methoxyphenyl)-2-phenylethane-1,2-dione **2h** were also applied in this unprecedented transformation, and it was found that the selectivity was nearly consistent with those described in Table 3. We believe these results nicely illustrate the high reactivity of this novel oxone-mediated protocol.

Finally, to ascertain whether this oxone-mediated oxidative transformation is applicable to other ketones, a range of ketone derivatives were investigated (for details, see the Supporting Information). It was shown that this oxone-mediated protocol can tolerate a range of α-diketones and represents a safe and effective approach for the preparation of carbonyl-containing oxindoles.

Since the peroxide bond of oxone can be activated by temperature to generate hydroxyl and sulfate radicals,[26] and these two radicals are powerful oxidants that are capable of initiating radical reaction,[27] we could not immediately rule out possible mechanisms involving the radical process. Accordingly, when radical scavengers, such as 2,2,6,6-tetramethyl-1-piperidinyloxy (TEMPO), and 2,6-di-*tert*-butyl-4-methylphenol (BHT) were added to the present reaction system, the desired transformation was completely suppressed (Scheme 3a,b), while the corresponding radical adduct 2,2,6,6-tetramethylpiperidin-1-yl benzoate (**4**) was obtained in 12% yield (for details, see the Supporting Information). These observations suggested that the reaction should proceed through a radical pathway. Subsequently, control experiments with possible intermediates were designed and investigated. When 2-hydroxy-1,2-diphenylethan-1-one (**5**) was utilized for this reaction, only a trace amount of the desired product **3a** was observed (Scheme 3c). Furthermore, benzaldehyde (**6**) and benzoic acid (**7**) did not react under these conditions (Scheme 3d,e). These results might exclude **5**, **6**, or **7** as the possible intermediates of this oxone-mediated transformation.

On the basis of these experimental evidence as well as previous related reports, two mechanistic scenarios are proposed and shown in Scheme 4 (by employing *N*-arylacrylamide **1a** and α-diphenyl ketone **2a** as the model). Consistent with the previously established mechanism for the Pd-catalyzed oxidative carbo-acylation reactions of 2-arylpyridines/indoles with these α-diketones,[9b,c] we propose that the benzoyl radical **C** is initially generated by the oxidative cleavage of α-diphenyl ketone **2a** with TBHP (method a, bottom right). Then, this active radical **C** selectively added to the carbon−carbon double bond of **1a** to lend alkyl radical **E**.[19−23] Through an intramolecular radical cyclization, this alkyl radical intermediate **E** would convert to the cyclized radical intermediate **F**.[19−23] Finally, abstraction of an aryl hydrogen in intermediate **F** by TBHP takes place to furnish carbonyl-containing oxindole **3a**.[19] Alternatively, in the oxone ($KHSO_5$)-mediated pathway (method b, top right), the initial step of the reaction involves the formation of intermediate α-hydroxyketone **A**, which had also been proposed by Borhan et al.[28] in an oxone-mediated oxidative esterification reaction. Since it has been demonstrated that the reaction should proceed through a radical pathway (Scheme 3a,b), an argument could be made that this α-hydroxyketone intermediate **A** could be further oxidized to radical intermediate **B**. It is very likely that the present heating conditions could induce these activated species such as hydroxyl and sulfate radicals, which could play the role of the oxidant in this step.[26,27] This proposal was also supported by the results obtained from entries 6−8 in Table 4. Further β-fragmentation of radical intermediate **B** (in an irreversible way) leads to C−C bond cleavage, affording benzoyl radical **C** along with the formation of intermediate **D**.[29] The unstable intermediate **D**, which could not be isolated, is rapidly split into some fragment ions. From this reaction, we detected the corresponding benzoic acid, which could also provide support in favor of the rationality of the aforementioned pathway. The subsequent reaction of benzoyl radical **C** and **1a** furnishes alkyl radical intermediate **E**,[19−23] which underwent an intramolecular radical cyclization to form the cyclized intermediate **F**.[19−23] Finally, oxidation of **F** afforded the corresponding carbocation **G**, followed by proton loss ($-H^+$), thus leading to carbonyl-containing oxindole **3a** (method b).[17a]

CONCLUSIONS

In summary, we have developed a novel protocol for the carboacylation/arylation of *N*-arylacrylamides via oxidative cleavage of $C(sp^2)-C(sp^2)$ bonds. Such a novel and green protocol, which utilizes transition-metal-free and simple reaction conditions, and inexpensive and readily available reagents, provides a convenient and highly efficient access to carbonyl-containing oxindoles. The good functional group compatibility profile suggests that our protocol could be an alternative route to these highly valuable compounds. Furthermore, the preparative practicality of this transformation is highlighted through gram-scale reaction of *N*-methyl-*N*-phenylmethacrylamide with α-diphenyl ketone by using oxone as a safe and environmentally benign oxidant. Further experimental studies to elucidate the mechanistic details and further investigation of relevant reactions based on this

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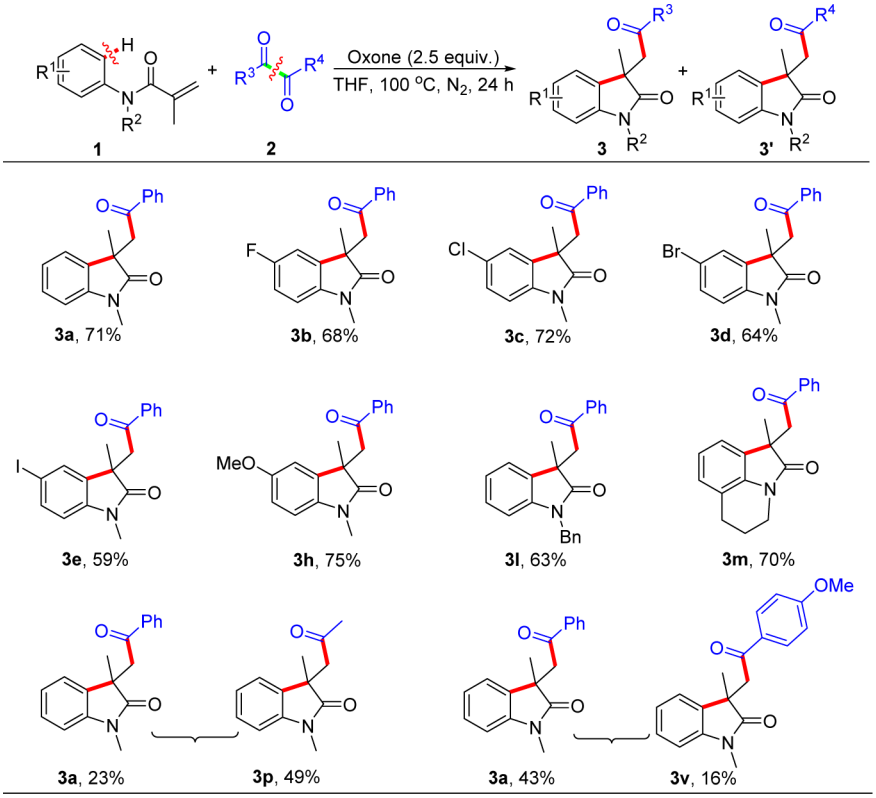
Table 5. Oxone-Mediated Oxidative Cleavage of C(sp^2)−C(sp^2) Bonds in α-Diketones Leading to Carbonyl-Containing Oxindoles[a,b]



[a]Reaction conditions: *N*-arylacrylamides (**1**, 0.3 mmol), α-diketones (**2**, 0.45 mmol), oxone (2.5 equiv), and THF (3.0 mL) at 100 °C under a N_2 atmosphere for 24 h. [b]Isolated yields.

transition-metal-free oxidative C(sp^2)−C(sp^2) bond cleavage mode are currently underway, and these studies will be reported in due course.

EXPERIMENTAL SECTION

General Methods. All reagents and solvent used were obtained commercially and used without further purification unless indicated otherwise. All solvents were dried and distilled prior to use according to the standard protocols. Products were purified by flash chromatography on silica gel (300−400 mesh, Merck) and were characterized by ^{1}H NMR, ^{13}C NMR, and all subject products were further characterized by HRMS. ^{1}H NMR spectra were recorded on 400 MHz in $CDCl_3$, and ^{13}C NMR spectra were recorded on 100 MHz in $CDCl_3$ using TMS as internal standard. Multiplicities are indicated as s (singlet), d (doublet), t (triplet), q (quintet), and m (multiplet), and coupling constants (*J*) are reported in hertz.

Preparation of *N*-Arylacrylamides. *N*-Arylacrylamide substrates **1a−o** were prepared according to the literature.[17,30]

Typical Experimental Procedure for the Synthesis of Carbonyl-Containing Oxindoles from *N*-Arylacrylamides and α-Diketones via TBHP-Mediated Cleavage of C(sp^2)−C(sp^2) Bonds. To a 25 mL Schlenk tube were added *N*-arylacrylamide **1** (0.3 mmol), α-diketone **2** (0.45 mmol), T-Hydro (0.9 mmol), and THF (2.0 mL). Then, the tube was charged with nitrogen and was stirred at 80 °C for 24 h until complete consumption of starting material, as monitored by TLC. After the reaction was finished, the reaction mixture was cooled to room temperature, and ethyl acetate (EtOAc) (20 mL) and water (10 mL) were added. The organic layer was separated, and the aqueous phase was extracted with ethyl acetate. The combined organic layers were dried over Na_2SO_4, filtered, and concentrated in vacuum. The resulting residue was purified by silica gel column chromatography (hexane/ethyl acetate) to afford the desired product.

Typical Experimental Procedure for the Synthesis of Carbonyl-Containing Oxindoles from *N*-Arylacrylamides and α-Diketones via Oxone-Mediated Cleavage of C(sp^2)−C(sp^2) Bonds. To a 25 mL Schlenk tube were added *N*-arylacrylamide **1** (0.3 mmol), α-diketone **2** (0.45 mmol), oxone (0.75 mmol), and THF (3.0 mL). Then, the tube was charged with nitrogen and was stirred at 100 °C for 24 h until complete consumption of starting material, as monitored by TLC. After the reaction was finished, the reaction mixture was cooled to room temperature, and ethyl acetate (EtOAc) (20 mL) and water (10 mL) were added. The organic layer was separated, and the aqueous phase was extracted with ethyl acetate. The combined organic layers were dried over Na_2SO_4, filtered, and concentrated in vacuum. The resulting residue was purified by silica gel column chromatography (hexane/ethyl acetate) to afford the desired product.

Experimental Procedure for the Gram-Scale Reaction of *N*-Arylacrylamide 1a with α-Diphenyl Ketone 2a (Table 4, entry 18). To a 100 mL Schlenk tube were added *N*-arylacrylamide **1a** (1 g, 5.7 mmol, 1.0 equiv), α-diphenyl ketone **2a** (1.8 g, 8.55 mmol, 1.5 equiv), oxone (2.5 equiv), and THF (15 mL). The tube was evacuated and backfilled with N_2 three times. The reaction mixture was stirred at 100 °C for 36 h. Upon completion, the solvent was evaporated under vacuum. Then, the residue was diluted by EtOAc and washed with H_2O. The organic phase was separated, dried over anhydrous Na_2SO_4, and filtered, and the solvent was then removed under vacuum. The resulting residue was purified by silica gel column chromatography (hexane/ethyl acetate) to afford the desired product **3a** in 65% yield (1.03 g).

*1,3-Dimethyl-3-(2-oxo-2-phenylethyl)indolin-2-one (**3a**).*[19−23] By following the typical procedure, the product was isolated as a colorless oil, 65.4 mg (78%), flash chromatography (hexane/ethyl acetate, 10/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, *J* = 7.6 Hz, 2H), 7.52 (t, *J* = 7.4 Hz, 1H), 7.40 (t, *J* = 7.3 Hz, 2H), 7.26 (t, *J* = 7.3 Hz, 2H), 7.14 (d, *J* = 7.2 Hz, 1H), 6.98 (t, *J* = 7.4 Hz, 1H), 6.90 (d, *J* = 7.7 Hz, 1H),

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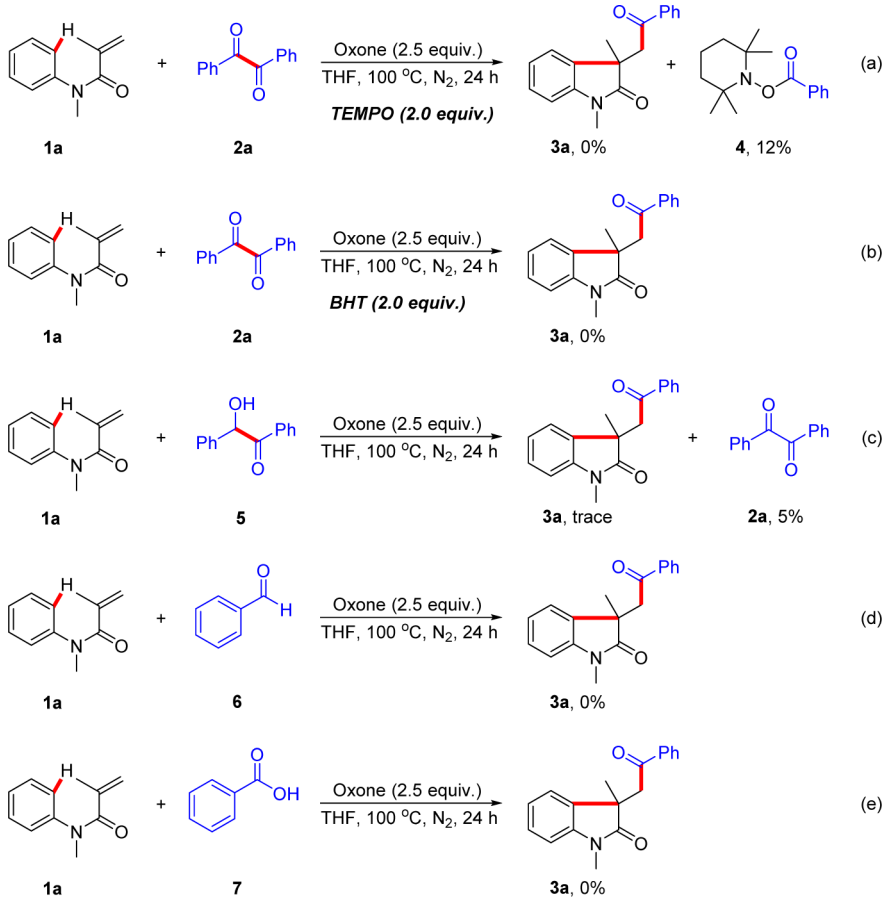
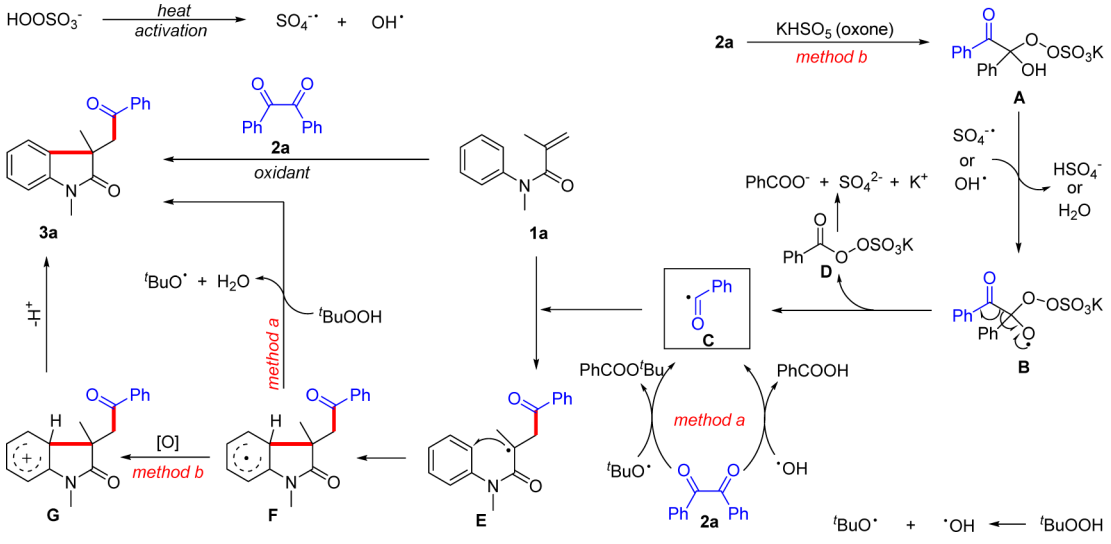
Scheme 3. Control Experiments



Scheme 4. Possible Mechanisms



3.75−3.64 (m, 2H), 3.32 (s, 3H), 1.45 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.1, 180.6, 143.8, 136.3, 133.7, 133.2, 128.5, 127.9, 127.8, 122.2, 121.7, 108.2, 46.0, 45.3, 26.4, 24.9; IR (neat film, cm^{-1}) 1705, 1622, 1348, 1190; HRMS *m*/*z* (ESI) calcd for $C_{18}H_{17}NO_2^+$ [M$^+$]: 279.1259; found 279.1261.

5-Fluoro-1,3-dimethyl-3-(2-oxo-2-phenylethyl)indolin-2-one (**3b**).[21] By following the typical procedure, the product was isolated as a yellow oil, 66 mg (74%), flash chromatography (hexane/ethyl acetate, 10/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, *J* = 7.5 Hz, 2H), 7.52 (t, *J* = 7.4 Hz, 1H), 7.39 (t, *J* = 7.7 Hz, 2H), 6.97−6.89 (m, 2H), 6.82−6.79 (m, 1H), 3.68 (s, 2H), 3.30 (s, 3H), 1.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.9, 180.3, 160.3, 157.9, 139.7, 136.1, 135.5, 135.4, 133.3, 128.5, 127. 9, 113.9, 113.7, 110.2, 110.0, 108.5, 108.4, 45.9, 45.7, 26.6, 24.7; IR (neat film, cm^{-1}) 1710, 1625, 1358, 1201; HRMS *m*/*z* (ESI) calcd for $C_{18}H_{16}FNO_2^+$ [M$^+$]: 297.1165; found 297.1169.

5-Chloro-1,3-dimethyl-3-(2-oxo-2-phenylethyl)indolin-2-one (**3c**).[21] By following the typical procedure, the product was isolated as a pale yellow oil, 67.8 mg (72%), flash chromatography (hexane/ethyl acetate, 10/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, *J* = 7.6 Hz,

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2H), 7.53 (t, J = 7.4 Hz, 1H), 7.40 (t, J = 7.7 Hz, 2H), 7.24−7.21 (m, 1H), 7.10 (d, J = 1.9 Hz, 1H), 6.82 (d, J = 8.3 Hz, 1H), 3.69 (s, 2H), 3.30 (s, 3H), 1.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.8, 180.2, 142.5, 136.1, 135.6, 133.3, 128.5, 128.0, 127.7, 127.5, 122.3, 109.1, 46.0, 45.4, 26.6, 24.8; IR (neat film, cm^{-1}) 1709, 1615, 1360, 1195; HRMS m/z (ESI) calcd for $C_{18}H_{16}ClNO_2^+$ [M$^+$]: 313.0870; found 313.0873.

5-Bromo-1,3-dimethyl-3-(2-oxo-2-phenylethyl)indolin-2-one (**3d**).[20c] By following the typical procedure, the product was isolated as a yellow oil, 83.8 mg (78%), flash chromatography (hexane/ethyl acetate, 10/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, J = 7.5 Hz, 2H), 7.54 (t, J = 7.4 Hz, 1H), 7.43−7.37 (m, 3H), 7.23 (d, J = 1.6 Hz, 1H), 6.78 (d, J = 8.4 Hz, 1H), 3.69 (s, 2H), 3.30 (s, 3H), 1.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.8, 180.0, 143.0, 136.0, 135.9, 133.4, 130.6, 128.6, 128.0, 125.0, 109.6, 46.1, 45.4, 26.6, 24.9; IR (neat film, cm^{-1}) 1711, 1619, 1362, 1188; HRMS m/z (ESI) calcd for $C_{18}H_{16}BrNO_2^+$ [M$^+$]: 357.0364; found 357.0368.

5-Iodo-1,3-dimethyl-3-(2-oxo-2-phenylethyl)indolin-2-one (**3e**).[21] By following the typical procedure, the product was isolated as a yellow solid, 97.2 mg (80%), flash chromatography (hexane/ethyl acetate, 10/1); mp 161−163 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, J = 7.4 Hz, 2H), 7.58−7.51 (m, 2H), 7.42−7.38 (m, 3H), 6.69 (d, J = 8.2 Hz, 1H), 3.69 (s, 2H), 3.29 (s, 3H), 1.41 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.8, 179.9, 143.6, 136.6, 136.3, 136.0, 133.3, 130.4, 128.5, 127.9, 110.2, 84.7, 46.0, 45.2, 26.5, 24.8; IR (neat film, cm^{-1}) 1715, 1677, 1339, 1201; HRMS m/z (ESI) calcd for $C_{18}H_{16}INO_2^+$ [M$^+$]: 405.0226; found 405.0231.

1,3,5-Trimethyl-3-(2-oxo-2-phenylethyl)indolin-2-one (**3g**).[23] By following the typical procedure, the product was isolated as a pale yellow oil, 72.2 mg (82%), flash chromatography (hexane/ethyl acetate, 10/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.85 (d, J = 7.5 Hz, 2H), 7.50 (d, J = 7.4 Hz, 1H), 7.39 (t, J = 7.7 Hz, 2H), 7.05 (d, J = 7.9 Hz, 1H), 6.96 (s, 1H), 6.79 (d, J = 7.9 Hz, 1H), 3.73−3.63 (m, 2H), 3.29 (s, 3H), 2.27 (s, 3H), 1.44 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.1, 180.5, 141.4, 136.3, 133.7, 133.1, 131.5, 128.4, 128.0, 127.9, 122.6, 107.8, 45.9, 45.3, 26.4, 24.9, 21.0; IR (neat film, cm^{-1}) 1716, 1638, 1348, 1191; HRMS m/z (ESI) calcd for $C_{19}H_{19}NO_2^+$ [M$^+$]: 293.1416; found 293.1412.

5-Methoxy-1,3-dimethyl-3-(2-oxo-2-phenylethyl)indolin-2-one (**3h**).[20a] By following the typical procedure, the product was isolated as a pale yellow oil, 78.9 mg (85%), flash chromatography (hexane/ethyl acetate, 6/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, J = 7.5 Hz, 2H), 7.51 (t, J = 7.4 Hz, 1H), 7.39 (t, J = 7.7 Hz, 2H), 6.82−6.76 (m, 3H), 3.73 (s, 3H), 3.67 (s, 2H), 3.29 (s, 3H), 1.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.1, 180.3, 155.7, 137.4, 136.3, 135.2, 133.2, 128.5, 128.0, 111.5, 110.0, 108.3, 55.7, 46.0, 45.7, 26.5, 24.9; IR (neat film, cm^{-1}) 1701, 1605, 1367, 1189; HRMS m/z (ESI) calcd for $C_{19}H_{19}NO_3^+$ [M$^+$]: 309.1365; found 309.1362.

1,3-Dimethyl-3-(2-oxo-2-phenylethyl)-7-phenylindolin-2-one (**3i**). By following the typical procedure, the product was isolated as a yellow oil, 74.6 mg (70%), flash chromatography (hexane/ethyl acetate, 10/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 (d, J = 7.4 Hz, 2H), 7.54−7.39 (m, 8H), 7.14−7.12 (m, 1H), 7.09 (dd, J = 7.7, 1.0 Hz, 1H), 6.99 (t, J = 7.5 Hz, 1H), 3.78−3.69 (m, 2H), 2.84 (s, 3H), 1.50 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.2, 181.7, 140.8, 139.2, 136.4, 134.8, 133.1, 130.8, 129.9, 128.4, 127.9, 127.6, 127.5, 125.5, 121.5, 120.6, 46.4, 44.6, 30.5, 25.4; IR (neat film, cm^{-1}) 1720, 1682, 1319, 1181; HRMS m/z (ESI) calcd for $C_{24}H_{21}NO_2^+$ [M$^+$]: 355.1572; found 355.1569.

7-Iodo-1,3-dimethyl-3-(2-oxo-2-phenylethyl)indolin-2-one (**3j**). By following the typical procedure, the product was isolated as a yellow oil, 66.9 mg (55%), flash chromatography (hexane/ethyl acetate, 10/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (d, J = 7.6 Hz, 2H), 7.64 (d, J = 8.0 Hz, 1H), 7.53 (t, J = 7.4 Hz, 1H), 7.40 (t, J = 7.7 Hz, 2H), 7.04 (d, J = 7.2 Hz, 1H), 6.66 (t, J = 7.7 Hz, 1H), 3.69 (d, J = 2.2 Hz, 5H), 1.40 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.9, 181.4, 144.3, 140.4, 136.9, 136.1, 133.3, 128.5, 127.9, 123.8, 121.3, 71.9, 46.3, 44.8, 30.4, 25.3; IR (neat film, cm^{-1}) 1713, 1685, 1327, 1188; HRMS m/z (ESI) calcd for $C_{18}H_{16}INO_2^+$ [M$^+$]: 405.0226; found 405.0230.

1-Ethyl-3,6-dimethyl-3-(2-oxo-2-phenylethyl)indolin-2-one and 1-Ethyl-3,4-dimethyl-3-(2-oxo-2-phenylethyl)indolin-2-one (**3k + 3k′**). By following the typical procedure, the product was isolated as a yellow oil, 73.8 mg (80%), flash chromatography (hexane/ethyl acetate, 10/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (t, J = 7.8 Hz, 3.11H), 7.50 (t, J = 7.3 Hz, 1.62H), 7.38 (t, J = 7.7 Hz, 3.09H), 7.15 (t, J = 7.8 Hz, 1H), 7.03 (d, J = 7.2 Hz, 0.58H), 6.79−6.72 (m, 3.11H), 3.97−3.66 (m, 6.73H), 2.37 (s, 1.91H), 2.30 (s, 2.9H), 1.49 (s, 3H), 1.42 (s, 2H), 1.37−1.27 (m, 6.47H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.1, 196.1, 180.4, 180.0, 143.0, 142.8, 137.6, 136.4, 136.2, 133.0, 132.9, 131.0, 130.6, 130.0, 128.4, 128.4, 127.9, 127.9, 127.5, 124.5, 122.4, 121.6, 109.3, 106.1, 46.1, 45.9, 45.0, 44.8, 34.7, 34.6, 25.0, 22.9, 21.8, 18.2, 12.3, 12.2; IR (neat film, cm^{-1}) 1720, 1725, 1681, 1690, 1335, 1341, 1190, 1203; HRMS m/z (ESI) calcd for $C_{20}H_{21}NO_2^+$ [M$^+$]: 307.1572; found 307.1569.

1-Benzyl-3-methyl-3-(2-oxo-2-phenylethyl)indolin-2-one (**3l**).[21] By following the typical procedure, the product was isolated as a white solid, 84.2 mg (79%), flash chromatography (hexane/ethyl acetate, 10/1); mp 158−160 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (d, J = 7.4 Hz, 2H), 7.50 (t, J = 7.4 Hz, 1H), 7.43−7.31 (m, 6H), 7.27−7.23 (m, 1H), 7.14−7.08 (m, 2H), 6.92 (t, J = 7.5 Hz, 1H), 6.73 (d, J = 8.0 Hz, 1H), 5.08 (d, J = 15.8 Hz, 1H), 4.96 (d, J = 15.8 Hz, 1H), 3.80- 3.70 (m, 2H), 1.50 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.9, 180.6, 142.8, 136.3, 136.2, 133.7, 133.1, 128.6, 128.4, 128.0, 127.6, 127.3, 127.2, 122.2, 121.6, 109.2, 45.8, 45.3, 43.9, 25.5; IR (neat film, cm^{-1}) 1722, 1621, 1348, 1192; HRMS m/z (ESI) calcd for $C_{24}H_{21}NO_2^+$ [M$^+$]: 355.1572; found 355.1575.

1-Methyl-1-(2-oxo-2-phenylethyl)-5,6-dihydro-4H-pyrrolo[3,2,1-ij]quinolin-2(1H)-one (**3m**).[23] By following the typical procedure, the product was isolated as a yellow oil, 80 mg (84%), flash chromatography (hexane/ethyl acetate, 6/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (d, J = 7.5 Hz, 2H), 7.50 (t, J = 7.4 Hz, 1H), 7.39 (t, J = 7.7 Hz, 2H), 7.00 (d, J = 7.5 Hz, 2H), 6. 87 (t, J = 7.4 Hz, 1H), 3.82−3.78 (m, 2H), 3.72−3.60 (m, 2H), 2.88−2.75 (m, 2H), 2.12−2.03 (m, 2H), 1.47 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.3, 179.4, 139.5, 136.4, 133.0, 132.1, 128.4, 127.9, 126.6, 121.6, 120.1, 119.8, 46.6, 45.8, 38.9, 24.6, 24.5, 21.2; IR (neat film, cm^{-1}) 1736, 1645, 1358, 1213; HRMS m/z (ESI) calcd for $C_{20}H_{19}NO_2^+$ [M$^+$]: 305.1416; found 305.1415.

(1-Methyl-2-oxo-3-(2-oxo-2-phenylethyl)indolin-3-yl)methyl Acetate (**3n**).[21] By following the typical procedure, the product was isolated as a pale yellow oil, 70 mg (69%), flash chromatography (hexane/ethyl acetate, 5/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (d, J = 7.6 Hz, 2H), 7.52 (t, J = 7.4 Hz, 1H), 7.40 (t, J = 7.6 Hz, 2H), 7.29 (t, J = 8.0 Hz, 1H), 7.18 (d, J = 7.6 Hz, 1H), 6.98 (t, J = 7.6 Hz, 1H), 6.91 (d, J = 8.0 Hz, 1H), 4.52 (d, J = 10.8 Hz, 1H), 4.17 (d, J = 10.8 Hz, 1H), 3.85 (d, J = 17.9 Hz, 1H), 3.70 (d, J = 17.9 Hz, 1H), 3.32 (s, 3H), 1.97 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.3, 177.2, 170.2, 144.6, 136.1, 133.3, 129.2, 128.6, 128.5, 127.9, 122.8, 122.2, 108.2, 67.5, 49.2, 41.9, 26.5, 20.6; IR (neat film, cm^{-1}) 1750, 1721, 1632, 1360, 1195; HRMS m/z (ESI) calcd for $C_{20}H_{19}NO_4^+$ [M$^+$]: 337.1314; found 337.1316.

2-((1-Methyl-2-oxo-3-(2-oxo-2-phenylethyl)indolin-3-yl)methyl)-isoindoline-1,3-dione (**3o**).[21] By following the typical procedure, the product was isolated as a pale yellow solid, 76.4 mg (60%), flash chromatography (hexane/ethyl acetate, 2/1); mp 205−207 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87−7.83 (m, 4H), 7.73−7.69 (m, 2H), 7.51 (t, J = 7.4 Hz, 1H), 7.39 (t, J = 7.6 Hz, 2H), 7.27 (t, J = 7.7 Hz, 1H), 7.11 (d, J = 7.2 Hz, 1H), 6.95−6.90 (m, 2H), 4.10−3.87 (m, 4H), 3.32 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 195. 6, 177.5, 168.2, 144.4, 136.1, 134.1, 133.2, 131.7, 129.7, 128.6, 128.5, 128.0, 123.5, 122.4, 122.0, 108.4, 49.4, 43.5, 43.3, 26.6; IR (neat film, cm^{-1}) 1762, 1725, 1620, 1355, 1189; HRMS m/z (ESI) calcd for $C_{26}H_{20}N_2O_4^+$ [M$^+$]: 424.1423; found 424.1426.

1,3-Dimethyl-3-(2-oxopropyl)indolin-2-one (**3p**).[22] By following the typical procedure, the product was isolated as a pale yellow oil, 34.5 mg (53%), flash chromatography (hexane/ethyl acetate, 6/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.20−7.16 (m, 1H), 7.07 (d, J = 7.2 Hz, 1H), 6.94 (t, J = 7.2 Hz, 1H), 6.79 (d, J = 7.6 Hz, 1H), 3.19 (s, 3H), 3.08−2.98 (m, 2H), 1.91 (s, 3H), 1.26 (s, 3H), 1.18 (s, 3H); ^{13}C NMR

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(100 MHz, $CDCl_3$) δ 204.6, 180.3, 143.7, 133.4, 127.9, 122.2, 121.8, 108.2, 50.5, 45.2, 29.9, 26.4, 24.3; IR (neat film, cm^{-1}) 1722, 1624, 1368, 1150; HRMS m/z (ESI) calcd for $C_{13}H_{15}NO_2^+$ [M^+]: 217.1103; found 217.1101.

*1,3-Dimethyl-3-(2-oxobutyl)indolin-2-one (**3q**).*[22] By following the typical procedure, the product was isolated as a pale yellow oil, 32.6 mg (47%), flash chromatography (hexane/ethyl acetate, 6/1); ^1H NMR (400 MHz, $CDCl_3$) δ 7.27−7.23 (m, 1H), 7.13 (d, J = 7.3 Hz, 1H), 7.00 (t, J = 7.5 Hz, 1H), 6.86 (d, J = 7.8 Hz, 1H), 3.27 (s, 3H), 3.08 (s, 2H), 2.36−2.20 (m, 2H), 1.33 (s, 3H), 0.89 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 207.3, 180.4, 143.7, 133.5, 127.8, 122.2, 121. 7, 108.2, 49.3, 45.1, 35.9, 26.4, 24.4, 7.3; IR (neat film, cm^{-1}) 1729, 1633, 1358, 1161; HRMS m/z (ESI) calcd for $C_{14}H_{17}NO_2^+$ [M^+]: 231.1259; found 231.1260.

*3-(2-(4-Fluorophenyl)-2-oxoethyl)-1,3-dimethylindolin-2-one (**3r**).*[23] By following the typical procedure, the product was isolated as a yellow oil, 22.3 mg (25%), flash chromatography (hexane/ethyl acetate, 10/1); ^1H NMR (400 MHz, $CDCl_3$) δ 7.87−7.84 (m, 2H), 7.25 (t, J = 7.6 Hz, 1H), 7.13 (d, J = 7.2 Hz, 1H), 7.05 (t, J = 8.6 Hz, 2H), 6.98 (t, J = 7.5 Hz, 1H), 6.90 (d, J = 7.6 Hz, 1H), 3.70−3.60 (m, 2H), 3.30 (s, 3H), 1.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.5, 180.4, 166.9, 164.4, 143.8, 133.6, 132.7, 130.6, 130.5, 127.8, 122.1, 121.7, 115.6, 115.4, 108.1, 45.8, 45.2, 26.4, 24.9; IR (neat film, cm^{-1}) 1711, 1620, 1348, 1157; HRMS m/z (ESI) calcd for $C_{18}H_{16}FNO_2^+$ [M^+]: 297.1165; found 297.1168.

*3-(2-(2-Fluorophenyl)-2-oxoethyl)-1,3-dimethylindolin-2-one (**3s**).* By following the typical procedure, the product was isolated as a yellow oil, 17.8 mg (20%), flash chromatography (hexane/ethyl acetate, 10/1); ^1H NMR (400 MHz, $CDCl_3$) δ 7.65−7.61 (m, 1H), 7.49−7.43 (m, 1H), 7.27−7.23 (m, 1H), 7.14−7.07 (m, 3H), 6.98 (t, J = 7.4 Hz, 1H), 6.90 (d, J = 8.0 Hz, 1H), 3.76−3.64 (m, 2H), 3.31 (s, 3H), 1.41 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.4, 194.2, 180.5, 163.2, 160.7, 143.8, 134.7, 134.7, 133.7, 130.6, 130.6, 127.7, 124.8, 124.7, 124.3, 124.3, 122.1, 121.5, 116.6, 116.4, 108.1, 50.8, 50.7, 45.4, 26.4, 25.0; IR (neat film, cm^{-1}) 1732, 1629, 1357, 1160; HRMS m/z (ESI) calcd for $C_{18}H_{16}FNO_2^+$ [M^+]: 297.1165; found 297.1167.

*4-(2-(1,3-Dimethyl-2-oxoindolin-3-yl)acetyl)benzonitrile (**3t**).*[19] By following the typical procedure, the product was isolated as a colorless oil, 14.6 mg (16%), flash chromatography (hexane/ethyl acetate, 10/1); ^1H NMR (400 MHz, $CDCl_3$) δ 7.90 (d, J = 8.2 Hz, 2H), 7.70 (d, J = 8.2 Hz, 2H), 7.29 (d, J = 8.0 Hz, 1H), 7.13 (d, J = 7.2 Hz, 1H), 6.99 (t, J = 7.6 Hz, 1H), 6.91 (d, J = 8.0 Hz, 1H), 3.66 (s, 2H), 3.30 (s, 3H), 1.45 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.9, 180.1, 143.8, 139.2, 133.2, 132.4, 128.4, 128.1, 122.3, 121.7, 117.8, 116.5, 108.3, 46.2, 45.3, 26.5, 24.9; IR (neat film, cm^{-1}) 1725, 1630, 1368, 1201; HRMS m/z (ESI) calcd for $C_{19}H_{16}N_2O_2^+$ [M^+]: 304.1212; found 304.1215.

*1,3-Dimethyl-3-(2-oxo-2-(p-tolyl)ethyl)indolin-2-one (**3u**).*[20c] By following the typical procedure, the product was isolated as a colorless oil, 29 mg (33%), flash chromatography (hexane/ethyl acetate, 10/1); ^1H NMR (400 MHz, $CDCl_3$) δ 7.64 (d, J = 8.4 Hz, 2H), 7.17−7.04 (m, 4H), 6.87 (t, J = 7.6 Hz, 1H), 6.80 (d, J = 7.6 Hz, 1H), 3.58 (q, J = 17.9 Hz, 2H), 3.22 (s, 3H), 2.27 (s, 3H), 1.35 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.6, 180.7, 143.9, 143.7, 133.8, 133.7, 129.1, 128.0, 127.7, 122.1, 121.6, 108.1, 45.8, 45.2, 26.4, 24.8, 21.5; IR (neat film, cm^{-1}) 1719, 1620, 1355, 1191; HRMS m/z (ESI) calcd for $C_{19}H_{19}NO_2^+$ [M^+]: 293.1416; found 293.1415.

*3-(2-(4-Methoxyphenyl)-2-oxoethyl)-1,3-dimethylindolin-2-one (**3v**).*[20a] By following the typical procedure, the product was isolated as a colorless oil, 17.6 mg (19%), flash chromatography (hexane/ethyl acetate, 6/1); ^1H NMR (400 MHz, $CDCl_3$) δ 7.81 (d, J = 8.8 Hz, 2H), 7.26−7.22 (m, 1H), 7.13 (d, J = 7.2 Hz, 1H), 6.96 (t, J = 7.5 Hz, 1H), 6.90−6.84 (m, 3H), 3.82 (s, 3H), 3.63 (q, J = 17.7 Hz, 2H), 3.30 (s, 3H), 1.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.5, 180.7, 163.4, 143.7, 133.8, 130.2, 129.4, 127.7, 122.0, 121.7, 113.5, 108.0, 55.3, 45.6, 45.3, 26.4, 24.9; IR (neat film, cm^{-1}) 1720, 1612, 1348, 1185; HRMS m/z (ESI) calcd for $C_{19}H_{19}NO_3^+$ [M^+]: 309.1365; found 309.1366.

*2,2,6,6-Tetramethylpiperidin-1-yl Benzoate (**4**).* The product was isolated as a colorless solid, 9.4 mg (12%), flash chromatography (hexane/ethyl acetate, 30/1); ^1H NMR (400 MHz, $CDCl_3$) δ 8.09−8.07 (m, 2H), 7.57 (t, J = 7.4 Hz, 1H), 7.46 (t, J = 7.6 Hz, 2H), 1.82−1.57 (m, 5H), 1.48−1.44 (m, 1H), 1.28 (s, 6H), 1.12 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 132.8, 129.7, 129.6, 128.4, 60.4, 39.1, 32.0, 20.8, 17.0; HRMS m/z (ESI) calcd for $C_{16}H_{23}NO_2^+$ [M^+]: 261.1729; found 261.1732.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.5b01977.

Copies of ^1H and ^{13}C spectra for all products (PDF)

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Notes

The authors declare no competing financial interest.

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