JOC The Journal of Organic Chemistry

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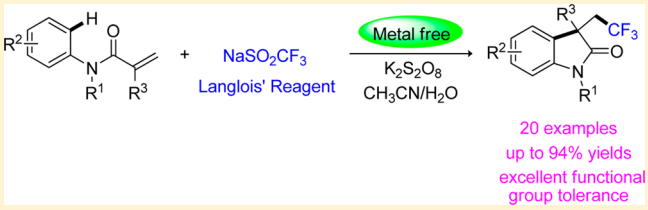
Metal-Free Direct Trifluoromethylation of Activated Alkenes with Langlois' Reagent Leading to CF_3-Containing Oxindoles

Wei Wei, Jiangwei Wen, Daoshan Yang, Xiaoxia Liu, Mengyuan Guo, Ruimei Dong, and Hua Wang*

The Key Laboratory of Life-Organic Analysis and Key Laboratory of Pharmaceutical Intermediates and Analysis of Natural Medicine, School of Chemistry and Chemical Engineering, Qufu Normal University, Qufu 273165, Shandong China

Supporting Information

ABSTRACT: A metal-free and cost-effective synthesis protocol has been initially proposed for the construction of CF_3-containing oxindoles via the direct oxidative trifluoromethylation of activated alkenes with Langlois' reagent (CF_3SO_2Na). The present methodology, which utilizes very cheap CF_3 reagent and a simple oxidant, provides a convenient and practical approach to CF_3-containing oxindoles with a wide variety of functional groups.

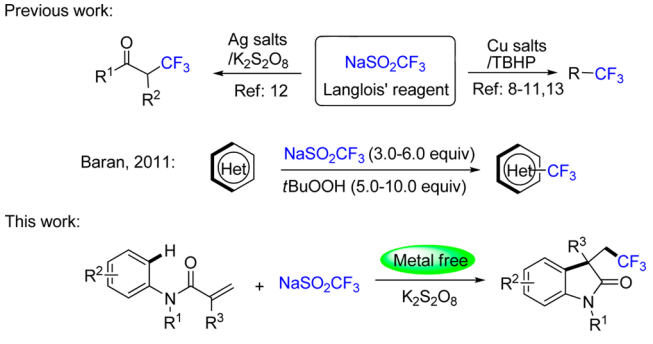


The incorporation of a CF_3 group into organic molecules of pharmacological relevance is of great interest in organic and medicinal chemistry because it could significantly enhance their chemical and metabolic stability, electronegativity, lipophilicity, and binding selectivity.[1,2] Over the past several years, a number of synthesis methods for introducing a CF_3 moiety into common synthetic scaffolds have been developed.[3] In particular, the synthesis of a CF_3-containing oxindoles has recently drawn increasing attention from chemists, owing to their importance for both pharmaceutical and synthetic research.[4−7] For example, in 2012, Liu's group reported the palladium-/ytterbium-catalyzed oxidative aryltrifluoromethylation reaction of activated alkenes for the synthesis of CF_3-containing oxindoles by using combination of the $TMSCF_3$/CsF/$PhI(OAc)_2$.[4] Sodeoka and Zhu proposed a complementary method for copper- or ruthenium-catalyzed aryltrifluoromethylation of simple alkenes with expensive Togni's reagent.[5,6] Very recently, Nevado and co-workers also described the copper- and tetrabutylammonium iodide-catalyzed aryltrifluoromethylation of activated alkenes by employing Togni's reagent as the CF_3 source.[7] Nevertheless, these well-established trifluoromethylation reactions usually require toxic transition-metal catalysts, expensive CF_3 reagents, and relatively complex reaction conditions, which have limited their wide applications in the field of synthetic chemistry and pharmaceutical industry. Therefore, there is still a great demand for the development of simple, convenient, economic, and metal-free trifluoromethylation strategies to construct CF_3-substituted oxindoles.

Recently, Langlois' reagent (CF_3SO_2Na), a cheap and stable solid CF_3 source, has emerged for the construction of CF_3-containing organic compounds via C−C bond formation.[8−13] Several studies have shown that the trifluoromethylations of heterocycles,[8] aryl boronic acids,[9] α,β-unsaturated carboxylic acids,[10] and unsaturated organotrifluoroborates[11] could be achieved by the combination of CF_3SO_2Na and Cu/TBHP catalytic systems. In 2013, Maiti et al. demonstrated the $AgNO_3$ (20 mol %) catalyzed oxidative trifluoromethylation of olefins with CF_3SO_2Na for the synthesis of α-CF_3-substituted ketones.[12] Very recently, Lipshutz and Liang reported $Cu(NO_3)_2$ (10 mol %) catalyzed trifluoromethylation of *N*-arylacrylamides with CF_3SO_2Na leading to oxindoles in the presence of 3.5 equiv of TBHP.[13] However, a toxic transition-metal catalytic system was still involved in these methods that have introduced CF_3SO_2Na as the CF_3. In 2011, Baran et al. described an efficient trifluoromethylation reaction of heterocycles with CF_3SO_2Na in the presence of excess amounts of TBHP (5−10 equiv).[14] In this paper, we report an efficient, cost-effective, and metal-free protocol for the direct oxidative trifluoromethylation of activated alkenes toward a variety of CF_3-containing oxindoles by using very cheapest CF_3SO_2Na as the CF_3 source and $K_2S_2O_8$ as the oxidant (Scheme 1). The protocol complements the methods of Lipschutz et al. and Baran et al. but avoids the use of copper catalysts and TBHP.

In an initial experiment, *N*-arylacrylamide **1a** was treated with CF_3SO_2Na in the presence of 1 equiv of $Na_2S_2O_8$ in CH_3CN/

Scheme 1. Trifluoromethylation Reactions with Langlois' Reagent (CF_3SO_2Na)

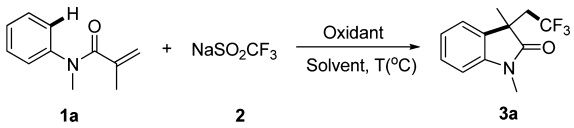


Received: March 4, 2014
Published: April 1, 2014

   dx.doi.org/10.1021/jo500515x | J. Org. Chem. 2014, 79, 4225−4230

H_2O (4:1) at 80 °C (Table 1, entry 1). Gratifyingly, the desired trifluoromethylated product **3a** was obtained in 18% yield.

Table 1. Optimization of the Reaction Conditions[a]



1a **2** **3a**

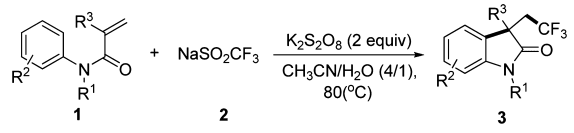
entry	oxidant (equiv)	solvent	yield[b] (%)
1	$Na_2S_2O_8$ (1)	CH_3CN/H_2O (4/1)	18
2	$K_2S_2O_8$ (1)	CH_3CN/H_2O (4/1)	33
3	$(NH_4)_2S_2O_8$ (1)	CH_3CN/H_2O (4/1)	20
4	TBHP (1)	CH_3CN/H_2O (4/1)	10
5	DTBP (1)	CH_3CN/H_2O (4/1)	n.r.
6	H_2O_2 (1)	CH_3CN/H_2O (4/1)	trace
7	$PhI(OAc)_2$ (1)	CH_3CN/H_2O (4/1)	trace
8	$K_2S_2O_8$ (1.5)	CH_3CN/H_2O (4/1)	65
9	$K_2S_2O_8$ (2)	CH_3CN/H_2O (4/1)	88
10	$K_2S_2O_8$ (2)	DME/H_2O (4/1)	39
11	$K_2S_2O_8$ (2)	$DMSO/H_2O$ (4/1)	35
12	$K_2S_2O_8$ (2)	DMF/H_2O (4/1)	45
13	$K_2S_2O_8$ (2)	1,4-dioxane/H_2O (4/1)	50
14	$K_2S_2O_8$ (2)	DMA/H_2O (4/1)	65
15	$K_2S_2O_8$ (2)	DCE/H_2O (4/1)	trace
16	$K_2S_2O_8$ (2)	CH_3CN/H_2O (2/1)	49
17	$K_2S_2O_8$ (2)	CH_3CN/H_2O (2/1.5)	29
18	$K_2S_2O_8$ (2)	CH_3CN/H_2O (1/1)	26
19	$K_2S_2O_8$ (2)	CH_3CN	35
20	$K_2S_2O_8$ (2)	H_2O	49
21	$K_2S_2O_8$ (2)	CH_3CN/H_2O (4/1)	Trace[c]
22	$K_2S_2O_8$ (2)	CH_3CN/H_2O (4/1)	61[d]
23	$K_2S_2O_8$ (2)	CH_3CN/H_2O (4/1)	77[e]
24	none	CH_3CN/H_2O (4/1)	n.r

[a]Reaction conditions: *N*-arylacrylamide **1a** (0.25 mmol), CF_3SO_2Na **2** (0.75 mmol), oxidant (1−2 equiv), solvent (2.5 mL), 80 °C, 12 h, under N_2. n.r. = no reaction. TBHP: *tert*-butyl hydroperoxide, 70% solution in water; DTBP: di-*tert*-butyl peroxide. [b]Isolated yields based on **1a**. [c]25 °C. [d]60 °C. [e]100 °C.

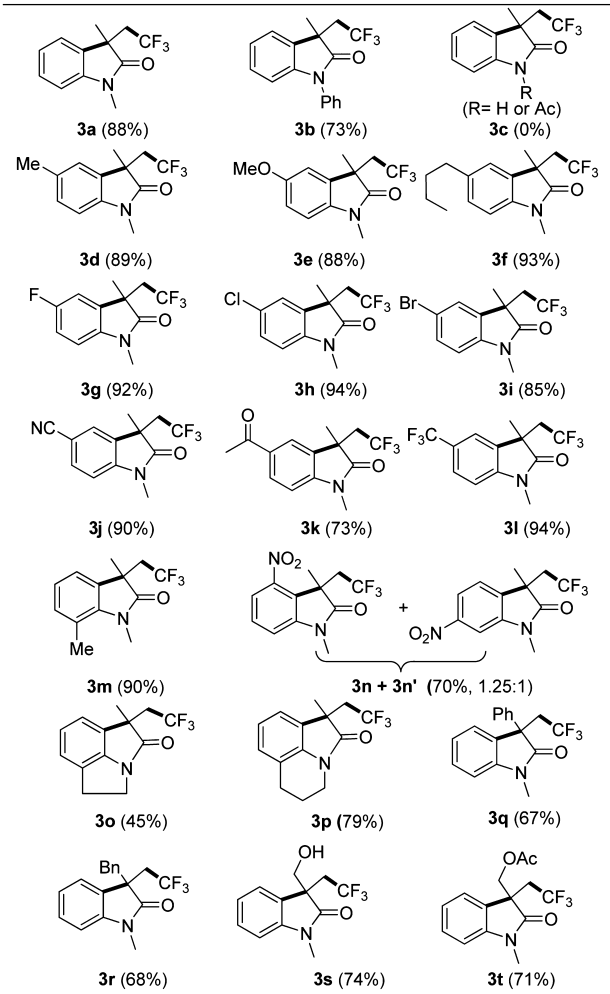
Encouraged by this result, we further optimized the reaction conditions by changing the oxidants. The investigation results showed that using $K_2S_2O_8$ (1 equiv) as an oxidant herein gave the best yield (33%), whereas other oxidants such as $(NH_4)_2S_2O_8$, TBHP, DTBP, H_2O_2, and $PhI(OAc)_2$ did not or only sluggishly promoted this reaction (Table 1, entries 3−7). We were pleased to find that increasing the amount of $K_2S_2O_8$ up to 2 equiv could improve the yield to 88% (Table 1, entries 8 and 9). The screening of a range of solvents revealed that the reaction performed in CH_3CN/H_2O (4:1) was significantly better than others (Table 1, entries 9−18). In contrast, product **3a** was isolated in low yield when the reaction was performed in the absence of H_2O or CH_3CN (Table 1, entries 19 and 20). This reaction is a heterogeneous reaction system; a small amount of water existing in this reaction system would improve the solubility of inorganic salts CF_3SO_2Na and $K_2S_2O_8$, but this reaction might be suppressed with the excess amount of water. As a result, higher yield of product might be obtained in MeCN/water (4:1) system. In addition, the best yield of **3a** was obtained when the reaction was performed at 80 °C (Table 1, entries 9 and 21−23). No conversion was observed in the absence of oxidant (Table 1, entry 24).

With the optimized conditions in hand, the scope and limitations of this reaction were investigated. As shown in Table 2, the effect of N-protecting groups on the reactions was first

Table 2. Trifluoromethylation of Different Activated Alkenes with CF_3SO_2Na[a,b]



1 **2** **3**



[a]Reaction conditions: *N*-arylacrylamide **1** (0.25 mmol), CF_3SO_2Na **2** (0.75 mmol), $K_2S_2O_8$ (2 equiv), CH_3CN/H_2O (2.5 mL, 4/1), 80 °C, 12−36 h, under N_2. [b]Isolated yields based on **1**.

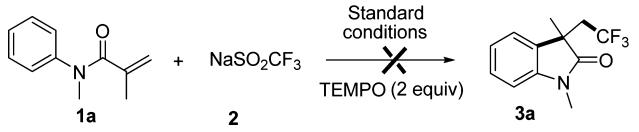
screened, and the results showed that substrates bearing alkyl and aryl protecting groups on the nitrogen are suitable for this reaction (**2a**,**b**), whereas N-free and acetyl *N*-arylacrylamides failed to give the desired products. Meanwhile, *N*-arylacrylamides with various substitution patterns at the aniline moieties were examined. In general, the substrates bearing electron-donating or electron-withdrawing substituents on the aniline moieties were suitable for this reaction, and the desired products were obtained in good yields (**3d**−**l**). It is noteworthy that various substituted functional groups such as F, Cl, Br, cyano, and carbonyl groups were compatible with this process to afford the corresponding oxindoles (**3g**−**k**), which could be used for further modifications at the substituted positions. The

dx.doi.org/10.1021/jo500515x | J. Org. Chem. 2014, 79, 4225−4230

sterically congested *ortho*-substituted substrate was also effectively reacted with CF_3SO_2Na to give product **3m** in 90% yields. Substituent groups at the *meta*-position of the phenyl ring afforded a mixture of two regioselective products (products **3n** and **3n′**). Notably, the cyclization of indoline and tetrahydroquinoline derivatives could afford tricyclic oxindoles **3o** and **3p** in 45% and 79% yields, respectively. Finally, the substrates bearing different substituents on olefin were evaluated. A variety of α-substituted alkenes with different functional groups such as aryl, benzyl, alcohol, and ester were well tolerated to this reaction, affording the desired products **3q−t** in moderate to good yields.

It is known that CF_3SO_2Na can be easily transformed to CF_3 radical in the presence of a transition-metal catalytic oxidation system,[8−14] which implies that this reaction might also proceed through a radical process. As shown in Scheme 2, when

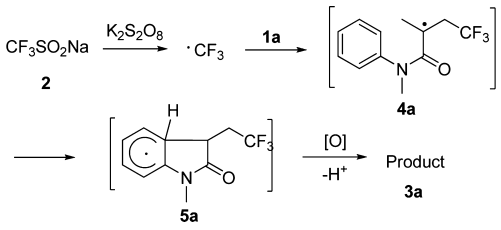
Scheme 2. Radical Trapping Experiment



TEMPO (2,2,6,6-tetramethyl-1-piperidinyloxy, a well-known radical-capturing species) was added to the present reaction system, the trifluoromethylation reaction was completely suppressed. This result suggested that the reaction should proceed through a radical pathway.

Based on the above experimental results and previous reports about oxindole synthesis,[15,16] a postulated reaction pathway was thereby proposed as shown in Scheme 3. Initially,

Scheme 3. Postulated Reaction Pathway



CF_3SO_2Na was converted into the CF_3 radical in the presence of $K_2S_2O_8$. Subsequently, the CF_3 radical selectively added to the carbon−carbon double bond of *N*-arylacrylamide **1a** leading to alkyl radical **4a**, which underwent an intramolecular radical cyclization to generate intermediate **5a**. Finally, oxidation of **5a** afforded the corresponding carbocation, followed by the loss of H^+, thus producing the CF_3-substituted oxindole **3a**.

In summary, we have developed a new metal-free synthesis strategy for the direct oxidative trifluoromethylation of activated alkenes toward the CF_3-containing oxindoles by using CF_3SO_2Na as the CF_3 source and $K_2S_2O_8$ as the oxidant. Such a green protocol, which utilizes metal-free reaction conditions, cheap CF_3 reagents, and cost-effective oxidants, provides a practical and efficient approach to various CF_3-containing oxindoles. It would extend the potential applications of CF_3-containing oxindoles bearing a quaternary carbon center in pharmaceutical and synthetic chemistry.

EXPERIMENTAL SECTION

General Methods. Chemicals were commercially available and were used without further purification unless otherwise stated. All solvents were dried according to standard procedures. ^1H, ^{13}C, and ^{19}F NMR spectra were obtained in $CDCl_3$ with TMS as internal standard (400 MHz ^1H, 100 MHz ^{13}C, 376 MHz ^{19}F) at room temperature, the chemical shifts (δ) are expressed in ppm, and J values are given in hertz. The following abbreviations are used to indicate the multiplicity: singlet (s), doublet (d), triplet (t), quartet (q), doublet of doublets (dd), doublet of triplets (dt), doublet of quartets (dq), and multiplet (m). All first-order splitting patterns were assigned on the basis of the appearance of the multiplet. Splitting patterns that could not be easily interpreted were designated as multiplet (m). HRMS data were obtained by ESI on a TOF mass analyzer. Column chromatography was performed on silica gel (200−300 mesh). *N*-Arylacrylamides **1** were prepared according to previous literatures.[17,18] Substrates **1q** and **1r** were prepared according to the literature.[18,19] Substrate **1s** and **1t** were prepared according to the literature.[17]

General Experimental Procedures. To a mixture of *N*-arylacrylamide **1** (0.25 mmol), CF_3SO_2Na **2** (0.75 mmol), and $K_2S_2O_8$ (0.5 mmol) in a 25 mL round-bottomed flack at room temperature under N_2 (balloon) was added CH_3CN/H_2O (4/1, 2.5 mL). The reaction vessel was allowed to stir at 80 °C for 12−36 h. After the reaction, the resulting mixture was extracted with EtOAc. The combined organic phase was dried over anhydrous Na_2SO_4, and the solvent was then removed under vacuum. The residue was purified by flash column chromatography using a mixture of petroleum ether and ethyl acetate as eluent to give the desired product **3**.

Experimental Procedure for Preliminary Mechanistic Studies with TEMPO. To a mixture of *N*-arylacrylamide **1a** (0.25 mmol), CF_3SO_2Na (0.75 mmol), TEMPO (0.5 mmol), and $K_2S_2O_8$ (0.5 mmol) was added CH_3CN/H_2O (4/1) 2.5 mL at room temperature under N_2 (balloon). The reaction vessel was allowed to stir for 12 h at 80 °C. After the reaction, the solution was concentrated in vacuum, and no desired product was detected.

*1,3-Dimethyl-3-(2,2,2-trifluoroethyl)indolin-2-one (**3a**).*[4,13] Compound **3a** was obtained in 88% yield (53.5 mg) according to the general procedure (12 h): ^1H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.34 (dt, J_1 = 1.0 Hz, J_2 = 7.7 Hz, 1H), 7.29 (d, J = 7.2 Hz, 1H), 7.12 (t, J = 7.6 Hz, 1H), 6.91 (d, J = 7.8 Hz, 1H), 3.26 (s, 3H), 2.84 (dq, J_1 = 10.7 Hz, J_2 = 15.2 Hz, 1H), 2.67 (dq, J_1 = 10.5 Hz, J_2 = 15.2 Hz, 1H), 1.43 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 178.5, 142.9, 131.0, 128.5, 125.3 (q, J = 276 Hz), 123.5 (q, J = 2 Hz), 122.7, 108.5, 44.4 (d, J = 2 Hz), 40.6 (q, J = 27 Hz), 26.4, 25.0; ^{19}F NMR (376 MHz, $CDCl_3$) δ −61.9; HRMS calcd for $C_{12}H_{12}F_3NONa$ $(M + Na)^+$ 266.0769, found 266.0770.

*3-Methyl-1-phenyl-3-(2,2,2-trifluoroethyl)indolin-2-one (**3b**).*[4,13] Compound **3b** was obtained in 73% yield (56 mg) according to the general procedure (12 h): ^1H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.55 (t, J = 7.4 Hz, 2H), 7.47−7.41 (m, 3H), 7.34 (d, J = 7.4 Hz, 1H), 7.25 (dd, J_1 = 1.2 Hz, J_2 = 7.8 Hz, 1H), 7.15 (dt, J_1 = 1.0 Hz, J_2 = 7.5 Hz, 1H), 6.86 (d, J = 7.9 Hz, 1H), 2.99 (dq, J_1 = 10.7 Hz, J_2 = 15.1 Hz, 1H), 2.75 (dq, J_1 = 10.4 Hz, J_2 = 15.1 Hz, 1H), 1.56 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 177.9, 143.0, 134.4, 130.7, 129.7, 128.4, 128.2, 126.6, 125.3 (q, J = 278 Hz), 123.8 (q, J = 1.3 Hz), 123.1, 109.8, 44.5 (d, J = 2 Hz), 41.1 (q, J = 27 Hz), 25.4; ^{19}F NMR (376 MHz, $CDCl_3$) δ −61.9; HRMS calcd for $C_{17}H_{14}F_3NONa$ $(M + Na)^+$ 328.0925, found 328.0925.

*1,3,5-Trimethyl-3-(2,2,2-trifluoroethyl)indolin-2-one (**3d**).*[4,13] Compound **3d** was obtained in 89% yield (57 mg) according to the general procedure (12 h): ^1H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.13 (d, J = 8.1 Hz, 1H), 7.10 (s, 1H), 6.79 (d, J = 7.8 Hz, 1H), 3.23 (s, 3H), 2.82 (dq, J_1 = 10.8 Hz, J_2 = 15.2 Hz, 1H), 2.65 (dq, J_1 = 10.6 Hz, J_2 = 15.2 Hz, 1H), 2.37 (s, 3H), 1.41 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 178.4, 140.5, 132.2, 131.1, 128.8, 125.3 (q, J = 276 Hz), 124.3 (q, J = 2 Hz), 108.2, 44.4 (d, J = 2 Hz), 40.6 (q, J = 28 Hz), 26.4, 25.0, 21.1; ^{19}F NMR (376 MHz, $CDCl_3$) δ −61.9; HRMS calcd for $C_{13}H_{14}F_3NONa$ $(M + Na)^+$ 280.0925, found 280.0931.

*5-Methoxy-1,3-dimethyl-3-(2,2,2-trifluoroethyl)indolin-2-one (**3e**).*[4,13] Compound **3e** was obtained in 88% yield (60 mg) according

dx.doi.org/10.1021/jo500515x | J. Org. Chem. 2014, 79, 4225−4230

to the general procedure (36 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 6.90 (d, J = 2.4 Hz, 1H), 6.85 (dd, J_1 = 2.5 Hz, J_2 = 8.5 Hz,1H), 6.79 (d, J = 2.4 Hz, 1H), 3.82 (s, 3H), 3.23 (s, 3H), 2.83 (dq, J_1 = 10.8 Hz, J_2 = 15.2 Hz, 1H), 2.64 (dq, J_1 = 10.5 Hz, J_2 = 15.2 Hz, 1H), 1.41 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 178.1, 156.1, 136.3, 132.4, 125.2 (q, J = 281 Hz), 112.6, 111.2 (q, J = 1.3 Hz), 108.7, 55.8, 44.8 (q, J = 2 Hz), 40.5 (q, J = 28 Hz), 26.5, 25.0; ^{19}F NMR (376 MHz, $CDCl_3$) δ −61.9; HRMS calcd for $C_{13}H_{14}F_3NO_2Na$ (M + Na)$^+$ 296.0874, found 296.0873.

*5-Butyl-1,3-dimethyl-3-(2,2,2-trifluoroethyl)indolin-2-one (**3f**).* Compound **3f** was obtained in 93% yield (69.5 mg) according to the general procedure (24 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.13 (dd, J_1 = 1.6 Hz, J_2 = 6.3 Hz, 1H), 7.11 (s, 1H), 6.81 (d, J = 8.0 Hz, 1H), 3.24 (s, 3H), 2.83 (dq, J_1 = 10.8 Hz, J_2 = 15.2 Hz, 1H), 2.69−2.60 (m, 3H), 1.64−1.56 (m, 2H), 1.42 (s, 3H), 1.36 (q, J = 7.4 Hz, 2H), 0.94 (t, J = 7.4 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 178.5, 140.6, 137.5, 131.0, 128.2, 125.3 (q, J = 280 Hz), 123.8 (q, J = 2 Hz), 108.1, 44.5 (d, J = 2 Hz), 40.6 (q, J = 28 Hz); 35.4, 34.0, 26.5, 25.0, 22.3, 13.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ −61.9; HRMS calcd for $C_{16}H_{20}F_3NONa$ (M + Na)$^+$ 322.1395, found 322.1392.

*5-Fluoro-1,3-dimethyl-3-(2,2,2-trifluoroethyl)indolin-2-one (**3g**).*[4,13] Compound **3g** was obtained in 92% yield (60 mg) according to the general procedure (12 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.06−7.01 (m, 2H), 6.82 (dd, J_1 = 4.2 Hz, J_2 = 9.2 Hz, 1H), 3.25 (s, 3H), 2.84 (dq, J_1 = 10.7 Hz, J_2 = 15.2 Hz, 1H), 2.65 (dq, J_1 = 10.4 Hz, J_2 = 15.2 Hz, 1H), 1.43 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 178.1, 159.3 (d, J = 240 Hz), 138.8 (d, J = 2 Hz), 132.6 (d, J = 8 Hz), 125.1 (q, J = 276 Hz), 114.8 (d, J = 23 Hz), 111.9 (q, J = 2 Hz), 111.6 (q, J = 2 Hz), 108.9 (d, J = 8 Hz), 44.8 (d, J = 2 Hz), 40.6 (q, J = 28 Hz), 26.6, 24.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ −62.0, −120.3; HRMS calcd for $C_{12}H_{11}F_4NONa$ (M + Na)$^+$ 284.0674, found 284.0671.

*5-Chloro-1,3-dimethyl-3-(2,2,2-trifluoroethyl)indolin-2-one (**3h**).*[4,13] Compound **3h** was obtained in 94% yield (65 mg) according to the general procedure (12 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.30 (dd, J_1 = 2.1 Hz, J_2 = 6.2 Hz, 1H), 7.26 (d, J = 1.8 Hz, 1H), 6.82 (d, J = 8.3 Hz, 1H), 3.24 (s, 3H), 2.86 (dq, J_1 = 10.7 Hz, J_2 = 15.2 Hz, 1H), 2.65 (dq, J_1 = 10.4 Hz, J_2 = 15.2 Hz, 1H), 1.42 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 177.9, 141.5, 132.7, 128.5, 128.1, 125.6 (q, J = 275 Hz), 124.1 (q, J = 1.3 Hz), 109.4, 44.6 (q, J = 2 Hz), 40.6 (q, J = 28 Hz), 26.6, 24.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ −62.0; HRMS calcd for $C_{12}H_{11}F_3ClNONa$ (M + Na)$^+$ 300.0379, found 300.0378.

*5-Bromo-1,3-dimethyl-3-(2,2,2-trifluoroethyl)indolin-2-one (**3i**).*[4,13] Compound **3i** was obtained in 85% yield (68 mg) according to the general procedure (12 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.46 (dd, J_1 = 1.9 Hz, J_2 = 6.3 Hz, 1H), 7.39 (d, J = 1.8 Hz, 1H), 6.78 (d, J = 8.3 Hz, 1H), 3.24 (s, 3H), 2.85 (dq, J_1 = 10.6 Hz, J_2 = 15.2 Hz, 1H), 2.66 (dq, J_1 = 10.4 Hz, J_2 = 15.2 Hz, 1H), 1.42 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 177.8, 142.0, 133.1, 131.4, 126.8 (q, J = 1.7 Hz), 125.1 (q, J = 277 Hz), 115.3, 109.9, 44.5 (d, J = 2 Hz), 40.3 (q, J = 28 Hz), 26.6, 24.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ −62.0; HRMS calcd for $C_{12}H_{11}F_3BrNONa$ (M + Na)$^+$ 343.9874, found 343.9875.

*1,3-Dimethyl-2-oxo-3-(2,2,2-trifluoroethyl)indoline-5-carbonitrile (**3j**).*[5b] Compound **3j** was obtained in 90% yield (60 mg) according to the general procedure (12 h): ^{1}H NMR (CDCl3, 400 MHz, ppm) δ 7.67 (dd, J_1 = 1.6 Hz, J_2 = 6.6 Hz, 1H), 7.54 (d, J = 1.2 Hz, 1H), 6.98 (d, J = 8.2 Hz, 1H), 3.29 (s, 3H), 2.88 (dq, J_1 = 10.6 Hz, J_2 = 15.3 Hz, 1H), 2.69 (dq, J_1 = 10.3 Hz, J_2 = 15.2 Hz, 1H), 1.45 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 178.1, 146.7, 133.9, 132.0, 127.0 (J = 1.3 Hz), 124.9 (q, J = 276 Hz), 119.0, 109.0, 106.0, 44.2 (d, J = 2 Hz), 40.5 (q, J = 28 Hz), 26.7, 24.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ −62.0; HRMS calcd for $C_{13}H_{11}F_3N_2ONa$ (M + Na)$^+$ 291.0721, found 291.0723.

*5-Acetyl-1,3-dimethyl-3-(2,2,2-trifluoroethyl)indolin-2-one (**3k**).* Compound **3k** was obtained in 73% yield (52 mg) according to the general procedure (24 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.99 (dd, J_1 = 1.6 Hz, J_2 = 8.2 Hz, 1H), 7.93 (s, 1H), 6.95 (d, J = 8.2 Hz, 1H), 3.30 (s, 3H), 2.88 (dq, J_1 = 10.6 Hz, J_2 = 15.2 Hz, 1H), 2.69 (dq, J_1 = 10.4 Hz, J_2 = 15.2 Hz, 1H), 2.61(s, 3H), 1.45 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 196.6, 178.7, 147.2, 132.3, 131.3, 130.5, 125.1 (q, J = 272 Hz), 123.4 (q, J = 1.3 Hz), 108.0, 44.2 (d, J = 3 Hz), 40.6 (q, J = 28 Hz), 26.7, 26.3, 25.0; ^{19}F NMR (376 MHz, CDCl3) δ −62.1; HRMS calcd for $C_{14}H_{14}F_3NO_2Na$ (M + Na)$^+$ 308.0874, found 308.0874.

*1,3-Dimethyl-3-(2,2,2-trifluoroethyl)-5-(trifluoromethyl)indolin-2-one (**3l**).*[13] Compound **3l** was obtained in 94% yield (73 mg) according to the general procedure (12 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.62 (dd, J_1 = 0.8 Hz, J_2 = 7.4 Hz, 1H), 7.52 (s, 1H), 6.98 (d, J = 8.2 Hz, 1H), 3.30 (s, 3H), 2.89 (dq, J_1 = 10.6 Hz, J_2 = 15.2 Hz, 1H), 2.71 (dq, J_1 = 10.4 Hz, J_2 = 15.2 Hz, 1H), 1.46 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 178.3, 145.9, 131.6, 126.4 (q, J = 4.0 Hz), 125.6, 125.2, 124.9, 123.6, 122.9, 120.7 (q, J = 2 Hz), 108.3, 44.3 (d, J = 2 Hz), 40.6 (q, J = 28 Hz), 26.6, 24.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ −61.6, −62.1; HRMS calcd for $C_{13}H_{11}F_6NONa$ (M + Na)$^+$ 334.0643, found 334.0642.

*1,3,7-Trimethyl-3-(2,2,2-trifluoroethyl)indolin-2-one (**3m**).* Compound **3m** was obtained in 90% yield (58 mg) according to the general procedure (12 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.10 (d, J = 7.5 Hz, 1H), 7.06 (d, J = 7.7 Hz, 1H), 7.98 (t, J = 7.4 Hz, 1H), 3.54 (s, 3H), 2.86 (dq, J_1 = 10.7 Hz, J_2 = 15.2 Hz, 1H), 2.65 (dq, J_1 = 10.5 Hz, J_2 = 15.2 Hz, 1H), 2.62 (s, 3H), 1.40 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 179.4, 140.7, 132.1, 131.6, 125.2 (q, J = 287 Hz), 122.5, 121.4 (d, J = 1 Hz), 120.0, 43.7 (q, J = 2 Hz), 40.9 (q, J = 22 Hz), 29.8, 25.5, 19.0; ^{19}F NMR (376 MHz, $CDCl_3$) δ −61.9; HRMS calcd for $C_{13}H_{14}NOF_3Na$ (M + Na)$^+$ 280.0925, found 280.0926.

*1,3-Dimethyl-4-nitro-3-(2,2,2-trifluoroethyl)indolin-2-one (**3n**) and 1,3-Dimethyl-6-nitro-3-(2,2,2-trifluoroethyl)indolin-2-one (**3n′**).*[4] Compounds **3n** and **3n′** were obtained in 70% total yield (50.5 mg) according to the general procedure (12 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 8.02 (dd, J_1 = 2.1 Hz, J_2 = 8.2 Hz, 0.8H), 7.93 (dd, J_1 = 1.0 Hz, J_2 = 8.5 Hz, 1H), 7.74 (d, J = 2.0 Hz, 0.8H), 7.54 (t, J = 7.9 Hz, 1H), 7.43 (d, J = 8.2 Hz, 0.8H), 7.23 (dd, J_1 = 0.8 Hz, J_2 = 7.8 Hz, 1H), 3.38 (dq, J_1 = 10.6 Hz, J_2 = 15.2 Hz, 1H), 3.33 (s, 2.4H), 3.32 (s, 3H), 3.04−2.89 (m, 1.8H), 2.72 (dq, J_1 = 10.3 Hz, J_2 = 15.2 Hz, 0.8H), 1.61 (s, 3H), 1.47 (s, 2.4H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 178.1, 177.8, 148.7, 146.1, 145.6, 144.2, 137.9, 125.6, 125.2 (q, J = 276 Hz), 124.9 (q, J = 276 Hz), 124.0 (q, J = 1.3 Hz), 118.6, 118.2, 114.0, 103.5, 44.6 (d, J = 3 Hz), 44.5 (d, J = 2 Hz), 40.5 (q, J = 28 Hz), 38.6 (q, J = 28 Hz), 27.1, 26.8, 24.8, 22.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ −62.0, −64.4.

*1,3-Dimethyl-4-nitro-3-(2,2,2-trifluoroethyl)indolin-2-one (**3n**):*[4] ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) 7.94 (dd, J_1 = 1.0 Hz, J_2 = 8.5 Hz, 1H), 7.54 (t, J = 7.9 Hz, 1H), 7.23 (dd, J_1 = 0.8 Hz, J_2 = 7.9 Hz, 1H), 3.39 (dq, J_1 = 10.6 Hz, J_2 = 15.2 Hz, 1H), 3.33 (s, 3H), 3.00 (dq, J_1 = 10.8 Hz, J_2 = 15.2 Hz, 1H), 1.62 (s, 3H); HRMS calcd for $C_{12}H_{11}F_3N_2O_3Na$ (M + Na)$^+$ 311.0619, found 311.0619.

*1,3-Dimethyl-6-nitro-3-(2,2,2-trifluoroethyl)indolin-2-one (**3n′**):*[4] ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 8.04 (dd, J_1 = 2.1 Hz, J_2 = 8.2 Hz, 1H), 7.75 (d, J = 2.1 Hz, 1H), 7.43 (d, J = 7.9 Hz, 1H), 3.35 (s, 3H), 2.94 (dq, J_1 = 10.4 Hz, J_2 = 15.2 Hz, 1H), 2.72 (dq, J_1 = 10.4 Hz, J_2 = 15.2 Hz, 1H), 1.48 (s, 3H); HRMS calcd for $C_{12}H_{11}F_3N_2O_3Na$ (M + Na)$^+$ 311.0619, found 311.0618.

*1-Methyl-1-(2,2,2-trifluoroethyl)-4,5-dihydropyrrolo[3,2,1-hi]-indol-2(1H)-one (**3o**).* Compound **3o** was obtained in 45% yield (29 mg) according to the general procedure (30 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 8.18 (d, J = 8.2 Hz, 1H), 7.25 (t, J = 7.0 Hz, 1H), 7.11 (t, J = 7.8 Hz, 1H), 4.56−4.45 (m, 2H), 3.64−3.52 (m, 1H), 3.22 (t, J = 8.0 Hz, 2H), 3.16−3.04 (m, 1H), 2.24 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 166.2, 143.9, 131.2, 127.5, 124.8 (q, J = 286 Hz), 124.7, 124.5, 118.8, 54.5 (d, J = 2 Hz), 50.5, 46.5 (q, J = 28 Hz), 29.4, 28.5; ^{19}F NMR (376 MHz, $CDCl_3$) δ −59.9; HRMS calcd for $C_{13}H_{12}F_3NONa$ (M + Na)$^+$ 278.0769, found 278.0771.

*1-Methyl-1-(2,2,2-trifluoroethyl)-5,6-dihydro-1H-pyrrolo[3,2,1-ij]-quinolin-2(4H)-one (**3p**).*[4,13] Compound **3p** was obtained in 79% yield (53 mg) according to the general procedure (30 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.13 (d, J = 7.4 Hz, 1H), 7.08 (d, J = 7.5 Hz, 1H), 6.99 (t, J = 7.5 Hz, 1H), 3.75 (t, J = 5.8 Hz, 2H), 2.84−2.61 (m, 4H), 2.07−2.01 (m, 2H), 1.44 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 177.3, 138.7, 129.7, 127.3, 125.4 (q, J = 278 Hz), 122.1, 121.5 (q, J = 2 Hz), 120.5, 45.7 (d, J = 2.0 Hz), 40.5 (q, J = 28 Hz),

dx.doi.org/10.1021/jo500515x | J. Org. Chem. 2014, 79, 4225−4230

39.1, 24.6, 24.5, 21.1; ^{19}F NMR (376 MHz, $CDCl_3$) δ −61.8; HRMS calcd for $C_{14}H_{14}F_3NONa$ $(M + Na)^+$ 292.0925, found 292.0924.

*1-Methyl-3-phenyl-3-(2,2,2-trifluoroethyl)indolin-2-one (**3q**).*[4,13] Compound **3q** was obtained in 67% yield (51 mg) according to the general procedure (22 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.42 (dt, J_1 = 1.2 Hz, J_2 = 8.9 Hz, 1H), 7.38−7.29 (m, 6H), 7.19 (dt, J_1 = 1.0 Hz, J_2 = 8.5 Hz, 1H), 6.97 (d, J = 7.8 Hz, 1H), 3.45 (dq, J_1 = 10.5 Hz, J_2 = 15.2 Hz, 1H), 3.25 (s, 3H), 3.07 (dq, J_1 = 10.5 Hz, J_2 = 15.0 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 176.9, 144.1, 138.6, 129.1, 128.8, 128.8, 128.0, 126.4, 126.1 (q, J = 2.0 Hz), 125.1 (d, J = 271 Hz), 122.6, 108.8, 51.9 (d, J = 2.0 Hz), 40.9 (q, J = 28 Hz), 26.6; ^{19}F NMR (376 MHz, $CDCl_3$) δ −61.1; HRMS calcd for $C_{17}H_{14}F_3NONa$ $(M + Na)^+$ 328.0925, found 328.0923.

*3-Benzyl-1-methyl-3-(2,2,2-trifluoroethyl)indolin-2-one (**3r**).* Compound **3r** was obtained in 68% yield (54 mg) according to the general procedure (12 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.27−7.22 (m, 2H), 7.12−7.05 (m, 4H), 6.79 (d, J = 6.7 Hz, 2H), 6.62 (d, J = 7.8 Hz, 1H), 3.11−3.01 (m, 3H), 2.97 (s, 3H), 2.81 (dq, J_1 = 10.3 Hz, J_2 = 15.1 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 177.3, 144.0, 134.0, 130.1, 128.6, 128.0, 127.6, 127.0, 125.3 (q, J = 276 Hz), 124.5 (q, J = 2.0 Hz), 122.1, 108.1, 50.1 (d, J = 2.0 Hz), 44.7, 39.5 (q, J = 28 Hz), 25.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ −61.2; HRMS calcd for $C_{18}H_{16}F_3NONa$ $(M + Na)^+$ 342.1082, found 342.1082.

*3-(Hydroxymethyl)-1-methyl-3-(2,2,2-trifluoroethyl)indolin-2-one (**3s**).*[4,13] Compound **3s** was obtained in 74% yield (48 mg) according to the general procedure (12 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.38 (dt, J_1 = 1.2 Hz, J_2 = 7.7 Hz, 1H), 7.30 (d, J = 7.2 Hz, 1H), 7.14 (dt, $J1$ = 0.9 Hz, $J2$ = 7.6 Hz, 1H), 6.94 (d, J = 7.8 Hz, 1H), 3.77 (d, J = 10.8 Hz, 1H), 3.68 (d, J = 11.1 Hz, 1H), 3.27 (s, 3H), 3.09 (dq, J_1 = 10.8 Hz, J_2 = 15.3 Hz, 1H), 2.83 (dq, J_1 = 10.4 Hz, J_2 = 15.3 Hz, 1H), 2.60 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 177.1, 143.7, 129.2, 127.0, 125.6 (q, J = 277 Hz), 124.0 (q, J = 1.3 Hz), 122.9, 108.7, 67.4, 49.8 (d, J = 2 Hz, 1H), 36.4 (q, J = 28 Hz), 26.4; ^{19}F NMR (376 MHz, $CDCl_3$) δ −61.5; HRMS calcd for $C_{12}H_{12}F_3NO_2Na$ $(M + Na)^+$ 282.0718, found 282.0721.

*(1-Methyl-2-oxo-3-(2,2,2-trifluoroethyl)indolin-3-yl)methyl Acetate (**3t**).*[4,13] Compound **3t** was obtained in 71% yield (53.5 mg) according to the general procedure (36 h): ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 7.37 (dt, J_1 = 1.1 Hz, J_2 = 7.8 Hz, 1H), 7.32 (d, J = 7.4 Hz, 1H), 7.12 (t, J = 7.6 Hz, 1H), 6.92 (d, J = 7.8 Hz, 1H), 4.42 (d, J = 10.9 Hz, 1H), 4.10 (d, J = 10.8 Hz, 1H), 3.27 (s, 3H), 2.95−2.82 (m, 2H), 1.99 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 175.1, 170.0, 143.6, 129.3, 126.6, 125.2 (q, J = 279 Hz), 124.6 (d, J = 2 Hz), 122.7, 108.5, 67.0, 48.2 (d, J = 2 Hz), 36.8 (q, J = 28 Hz), 26.5, 20.5; ^{19}F NMR (376 MHz, $CDCl_3$) δ −61.4; HRMS calcd for $C_{14}H_{14}F_3NO_3Na$ $(M + Na)^+$ 324.0823, found 324.0820.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

^{1}H and ^{13}C NMR spectra for all compounds prepared. This material is available free of charge via the Internet at http://pubs.acs.org/.

■ AUTHOR INFORMATION

Corresponding Author

*Tel: +86 537 4458317. Fax: +86 537 4458317. E-mail: huawang_qfnu@126.com.

Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

This work was supported by the National Natural Science Foundation of China (Nos. 21302109, 21302110, and 21375075), the Taishan Scholar Foundation of Shandong Province, the Excellent Middle-Aged and Young Scientist Award Foundation of Shandong Province (BS2013YY019), and the Scientific Research Foundation of Qufu Normal University (BSQD 2012020).

■ REFERENCES

(1) (a) Banks, R. E., Smart, B. E., Tatlow, J. C., Eds. *Organofluorine Chemistry: Principles and Commercial Applications*; Plenum Press: New York, 1994. (b) Kirsch, P. *in Modern Fluoroorganic Chemistry: Synthesis Reactivity Applications*; Wiley-VCH: Weinheim, 2004. (c) Ojima, I. In *Fluorine in Medicinal Chemistry and Chemical Biology*; Wiley-Blackwell: Chichester, 2009. (d) Purser, S.; Moore, P. R.; Swallow, S.; Governeur, V. *Chem. Soc. Rev.* **2008**, *37*, 320−330.

(2) (a) Müller, K.; Faeh, C.; Diederich, F. *Science* **2007**, *317*, 1881−1886. (b) Furuya, T.; Kamlet, A. S.; Ritter, T. *Nature* **2011**, *473*, 470−477. (c) Parsons, A. T.; Buchwald, S. L. *Nature* **2011**, *480*, 184−185. (d) Tomashenko, O.; Grushin, V. V. *Chem. Rev.* **2011**, *111*, 4475−4521. (e) Wu, X. F.; Neumann, H.; Beller, M. *Chem.—Asian J.* **2012**, *7*, 1744−1754. (f) Furuya, T.; Kuttruff, C. A.; Ritter, T. *Curr. Opin. Drug Discovery Dev.* **2008**, *11*, 803−819. (g) Lectard, S.; Hamashima, Y.; Sodeoka, M. *Adv. Synth. Catal.* **2010**, *352*, 2708−2732.

(3) For selected examples, see: (a) Dubinina, G. G.; Furutachi, H.; D. Vicic, A. *J. Am. Chem. Soc.* **2008**, *130*, 8600−8601. (b) Cho, E. J.; Senecal, T. D.; Zhang, T. Y.; Watson, D. A.; Buchwald, S. L. *Science* **2010**, *328*, 1679−1681. (c) Chu, L.; Qing, F.-L. *J. Am. Chem. Soc.* **2010**, *132*, 7262−7263. (d) Morimoto, H.; Tsubogo, T.; Litvinas, N. D.; Hartwig, J. F. *Angew. Chem., Int. Ed.* **2011**, *50*, 3793−3798. (e) Parsons, A. T.; Buchwald, S. L. *Angew. Chem., Int. Ed.* **2011**, *50*, 9120−9123. (f) Wang, X.; Ye, Y.; Zhang, S.; Feng, J.; Xu, Y.; Zhang, Y.; Wang, J. *J. Am. Chem. Soc.* **2011**, *133*, 16410−16413. (g) Xu, J.; Fu, Y.; Luo, D.-F.; Jiang, Y.-Y.; Xiao, B.; Liu, Z.-J.; Gong, T.-J.; Liu, L. *J. Am. Chem. Soc.* **2011**, *133*, 15300−15303. (h) Zhang, X.-G.; Dai, H.-X.; Wasa, M.; Yu, J.-Q. *J. Am. Chem. Soc.* **2012**, *134*, 11948−11951. (i) Shimizu, R.; Egami, H.; Hamashima, Y.; Sodeoka, M. *Angew. Chem., Int. Ed.* **2012**, *51*, 4577−4580. (j) Studer, A. *Angew. Chem., Int. Ed.* **2012**, *51*, 8950−8958. (k) Egami, H.; Kawamura, S.; Miyazaki, A.; Sodeoka, M. *Angew. Chem., Int. Ed.* **2013**, *52*, 7841−7844. (l) Mizuta, S.; Verhoog, S.; Engle, K. M.; Khotavivattana, T.; Duill, M. O.; Wheelhouse, K.; Rassias, G.; Mdebielle, M.; Gouverneur, V. *J. Am. Chem. Soc.* **2013**, *135*, 2505−2508.

(4) Mu, X.; Wu, T.; Wang, H. Y.; Guo, Y. L.; Liu, G. S. *J. Am. Chem. Soc.* **2012**, *134*, 878−881.

(5) (a) Egami, H.; Shimizu, R.; Kawamura, S.; Sodeoka, M. *Angew. Chem., Int. Ed.* **2013**, *52*, 4000−4003. (b) Egami, H.; Shimizu, R.; Sodeoka, M. *J. Fluorine Chem.* **2013**, *152*, 51−55.

(6) Xu, P.; Xie, J.; Xue, Q. C.; Pan, C. D.; Cheng, Y. X.; Zhu, C. J. *Chem.—Eur. J.* **2013**, *19*, 14039−14042.

(7) (a) Kong, W.; Casimiro, M.; Merino, E.; Nevado, C. *J. Am. Chem. Soc.* **2013**, *135*, 14480−14483. (b) Kong, W.; Casimiro, M.; Fuentes, N.; Merino, E.; Nevado, C. *Angew. Chem., Int. Ed.* **2013**, *52*, 13086−13090.

(8) Langlois, B. R.; Laurent, E.; Roidot, N. *Tetrahedron Lett.* **1991**, *32*, 7525−7528.

(9) Ye, Y. D.; Kuenzi, S. A.; Sanford, M. S. *Org. Lett.* **2012**, *14*, 4979−4981.

(10) Li, Z. J.; Cui, Z. L.; Liu, Z. Q. *Org. Lett.* **2013**, *15*, 406−409.

(11) Presset, M.; Oehlrich, D.; Rombouts, F.; Molander, G. A. *J. Org. Chem.* **2013**, *78*, 12837−12843.

(12) Deb, A.; Manna, S.; Modak, A.; Patra, T.; Maity, S.; Maiti, D. *Angew. Chem., Int. Ed.* **2013**, *52*, 9747−9750.

(13) Yang, F.; Klumphu, P.; Liang, Y.-M.; Lipshutz, B. H. *Chem. Commun.* **2014**, *50*, 936−938.

(14) Ji, Y. N.; Brueckl, T.; Baxter, R. D.; Fujiwara, Y.; Seiple, I. B.; Su, S.; Blackmond, D. G.; Baran, P. S. *Proc. Natl. Acad. Sci. U.S.A.* **2011**, *108*, 14411−14415.

(15) Selective examples for the synthesis of oxindoles, see: (a) Wei, W.-T.; Zhou, M.-B.; Fan, J.-H.; Liu, W.; Song, R.-J.; Liu, Y.; Hu, M.; Xie, P.; Li, J.-H. *Angew. Chem., Int. Ed.* **2013**, *52*, 3638−3641. (b) Li, Y.-M.; Sun, M.; Wang, H.-L.; Tia, Q.-P.; Yang, S.-D. *Angew. Chem., Int. Ed.* **2013**, *52*, 3972−3976. (c) Wei, X.-H.; Li, Y.-M.; Zhou, A.-X.; Yang, T.-T.; Yang, S.-D. *Org. Lett.* **2013**, *15*, 4151−4153. (d) Wang, H.; Guo,

L.-N.; Duan, X.-H. *Adv. Synth. Catal.* **2013**, *355*, 2222−2226. (e) Wei, X. H.; Li, Y.; M; Zhou, A. X.; Yang, T. T.; Yang, S. D. *Org. Lett.* **2013**, *15*, 4158−4161. (f) Xu, X.; Tang, Y.; Li, X.; Hong, G.; Fang, M.; Du, X. *J. Org. Chem.* **2014**, *79*, 446−451.

(16) Some examples for the metal-free oxidative difunctionalization of alkenes leading to oxindoles see: (a) Wu, T.; Zhang, H.; Liu, G. *Tetrahedron* **2012**, *68*, 5229−5233. (b) Zhou, M.-B.; Song, R.-J.; Ouyang, X.-H.; Liu, Y.; Wei, W.-T.; Deng, G.-B.; Li, J.-H. *Chem. Sci.* **2013**, *4*, 2690−2694. (c) Meng, Y.; Guo, L.-N.; Wang, H.; Duan, X.-H. *Chem. Commun.* **2013**, *49*, 7540−7542. (d) Matcha, K.; Narayan, R.; Antonchick, A. P. *Angew. Chem., Int. Ed.* **2013**, *52*, 7985−7989. (e) Li, X.; Xu, X.; Hu, P.; Xiao, X.; Zhou, C. *J. Org. Chem.* **2013**, *78*, 7343−7348. (f) Li, Y.-M.; Wei, X.-H.; Li, X.-A.; Yang, S.-D. *Chem. Commun.* **2013**, *49*, 11701−11703. (g) Shen, T.; Yuan, Y. Z.; Jiao, N. *Chem. Commun.* **2014**, *50*, 554−556.

(17) Pinto, A.; Jia, Y.; Neuville, L.; Zhu, J. *Chem.—Eur. J.* **2007**, *13*, 961−967.

(18) Ayitou, A. A.-L.; Sivaguru, J. *Chem. Commun.* **2011**, *47*, 2568−2570.

(19) Zhang, Q.-Q.; Xie, J.-H.; Yang, X.-H.; Xie, J.-B.; Zhou, Q.-L. *Org. Lett.* **2012**, *14*, 6158−6161.

dx.doi.org/10.1021/jo500515x | *J. Org. Chem.* 2014, 79, 4225−4230