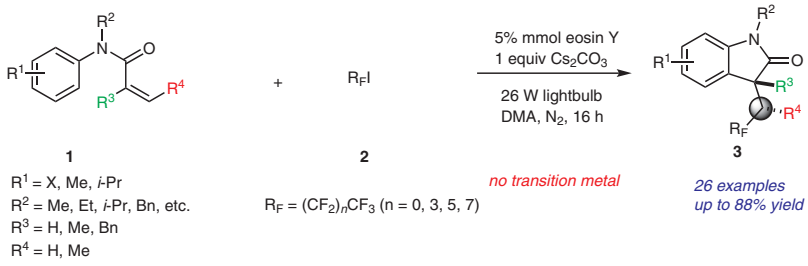
Synlett Z. Yang, A. Tang Letter

Synthesis of Perfluoroalkyl-Substituted Oxindoles through Organophotoredox-Catalyzed Perfluoroalkylation of *N*-arylacrylamides with Perfluoroalkyl Iodides

Zhiyong Yang*
Anjiang Tang

School of Chemical Engineering, Guizhou Institute of Technology, Guiyang, 550003, P. R. of China
weyouthem@163.com



Received: 01.01.2019
Accepted after revision: 10.02.2019
Published online: 15.04.2019
DOI: 10.1055/s-0037-1611781; Art ID: st-2019-k1743-l

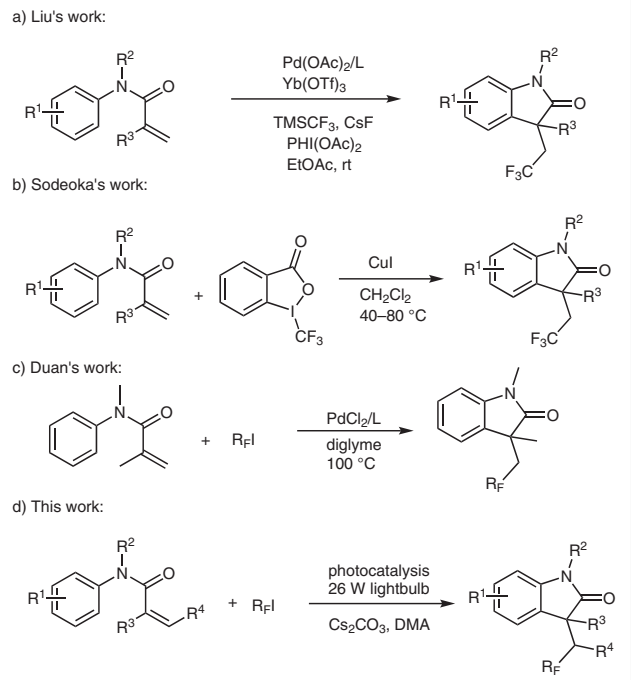
Abstract An efficient process was developed for the perfluoroalkylation of *N*-arylacrylamides through an organocatalyzed photoredox/cyclization reaction of *N*-arylacrylamides with inexpensive perfluoroalkyl iodide reagents. The reaction employs an inexpensive organic dye, eosin Y, as the photoredox catalyst and is run under irradiation by a 26 W LED lightbulb.

Key words oxindoles, cyclization, perfluoroalkylation, photoredox reaction

Fluoroalkylated molecules are important due to their unique physical, chemical, and biological properties, which can be applied in a wide range of fields, including materials, agrochemicals, and pharmaceuticals.[1,2] Among organofluorine compounds, trifluoromethyl- and perfluoroalkyl (R_F)-substituted compounds have attracted significant interest, particularly because of their metabolic stability, lipophilicity, and electron-withdrawing properties.[1,2] In recent decades, numerous methods for the introduction of trifluoromethyl and perfluoroalkyl groups to form alkyl–R_F bonds[3] and aryl–R_F bonds[4–7] have been developed. In particular, practical procedures that do not require the use of expensive catalysts are important and have obvious advantages in terms of cost.[6d,8–12] For example, perfluorinated alkyl radicals can be generated from perfluoroalkyl iodides by treatment with sodium dithionate, and new C–C bond can be formed through subsequent radical addition and substitution under mild conditions.[8–10] Another more attractive approach is organocatalytic photoredox trifluoromethylation and perfluoroalkylation. Since MacMillan and co-workers introduced the concept of organophotoredox fluoroalkylation, which has been successfully applied in the organocatalytic α-trifluoromethylation and α-perfluoroalkylation of carbonyl compounds,[11] perfluoroalkylation reactions through photoredox catalysis have been developed by the groups of König,[12] Sanford,[6d] Dolbier,[13] Qing,[7e,14] and others.[15]

Numerous synthetic strategies have recently been developed for the syntheses of oxindoles because of the desirable biological properties of these compounds.[16–22] Among these strategies, protocols for the synthesis of fluorine-containing oxindoles have been developed by the groups of Liu, Sodeoka, Nevado, Sheng, Duan, and others.[20–22] Liu and Sodeoka synthesized perfluoroalkyl-substituted oxindoles by using $TMSCF_3$ or 1-trifluoromethyl-1,2-benziodoxol-3-(1*H*)-one (Togni's reagent), respectively, as sources of the trifluoromethyl group [Schemes 1(a) and 1(b)]. Because the generation of perfluoroalkyl radicals by using inexpensive R_FI rather than Togni's reagent is more attractive, Duan applied this strategy to the synthesis of perfluorinated oxindoles through Pd-catalyzed alkarylation of acrylamides with R_FI [Scheme 1(c)].[21c] Inspired by these pioneering works, we have developed a simple procedure for the synthesis of perfluoroalkylated oxindoles through perfluoroalkyl radical-mediated cyclization of *N*-arylacrylamides with R_FI in the presence of an organophotoredox catalyst under visible light [Scheme 1(d)].

Our initial experiments involved the reaction of *N*-methyl-*N*-phenylmethacrylamide (**1a**) with *n*-C_4F_9I catalyzed by $Ru(bpy)_3Cl_2{\cdot}6H_2O$. When **1a** was treated with three equivalents of *n*-C_4F_9I in the presence of 5% mmol of $Ru(bpy)_3Cl_2{\cdot}6H_2O$ and one equivalent of K_2CO_3 in DMF at 60 °C for 16 hours, the desired (perfluoroalkyl)oxindole **3a** was obtained in 32% yield (Table 1, entry 1). Because a large amount of **1a** remained intact, we screened various reaction conditions such as the temperature, base, solvent, and catalyst in an attempt to obtain a better yield. When the temperature was increased to 65 or 70 °C, the yield increased by about 19% (entries 2 and 3). A further increase in the yield of the **3a** to 61% was obtained when K_2CO_3 was re-

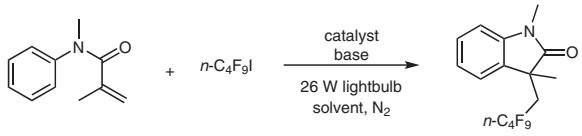


Scheme 1 Synthesis of fluorine-containing oxindoles

placed with Cs_2CO_3 (entry 4). However, replacing K_2CO_3 with other bases (Na_2CO_3, NaOAc, $NaHCO_3$, or NaOH) had a negative effect on the yield; when no base was used, only a 5% yield was obtained (entries 5–9). The effect of various solvent on the yield was also examined. When DMF was replaced with *N*,*N*-dimethylacetamide (DMA), the yield rose to 75% (entry 10). Because organic dye photocatalysts have been shown to be as effective as $Ru(bpy)_3Cl_2{\cdot}6H_2O$, we replaced this photocatalyst with eosin Y. As expected, this had beneficial effect on the reaction, giving a yield of 85% under the optimized conditions (entry 11). Changing the solvent to toluene, diglyme, or MeOH afforded no product, and the starting material remained intact (entries 13–15). A control reaction showed that visible light was essential for this transformation to proceed (entry 16). On the basis of these results, the optimal reaction conditions for the reaction were one equivalent of *N*-methyl-*N*-phenylmethacrylamide (**1a**) with three equivalents of $F_3CCF_{2s}I$ and one equivalent of Cs_2CO_3 in the presence of 5 mmol% eosin Y in DMA with irradiation by a 26 W compact LED lightbulb at 65 °C for 16 hours.

The scope and limitations of this reaction were next examined (Table 2). The reaction worked satisfactorily when an electron-donating or electron-withdrawing substituent was present in the *ortho*-or *para*-position of the aromatic ring of the *N*-methyl-*N*-arylmethacrylamide, affording the desired products **3a–i** in yields of 61–85% (Table 2, entries 1–9). All substrates with *N*-protecting alkyl or aryl groups

Table 1 Reaction Conditions Optimization[a]



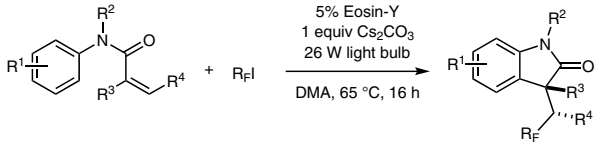
1a **2a** **3a**

Entry	Catalyst	Base	Solvent	Temp (°C)	Yield[b] (%)
1	$Ru(bpy)_3Cl_2{\cdot}6H_2O$	K_2CO_3	DMF	60	42
2	$Ru(bpy)_3Cl_2{\cdot}6H_2O$	K_2CO_3	DMF	65	51
3	$Ru(bpy)_3Cl_2{\cdot}6H_2O$	K_2CO_3	DMF	70	49
4	$Ru(bpy)_3Cl_2{\cdot}6H_2O$	Cs_2CO_3	DMF	65	61
5	$Ru(bpy)_3Cl_2{\cdot}6H_2O$	Na_2CO_3	DMF	65	44
6	$Ru(bpy)_3Cl_2{\cdot}6H_2O$	NaOAc	DMF	65	36
7	$Ru(bpy)_3Cl_2{\cdot}6H_2O$	$NaHCO_3$	DMF	65	31
8	$Ru(bpy)_3Cl_2{\cdot}6H_2O$	–	DMF	65	5
9	$Ru(bpy)_3Cl_2{\cdot}6H_2O$	NaOH	DMF	65	45
10	$Ru(bpy)_3Cl_2{\cdot}6H_2O$	Cs_2CO_3	DMA	65	75
11	eosin Y	Cs_2CO_3	DMA	65	85
12	eosin Y	Cs_2CO_3	DMSO	65	43
13	eosin Y	Cs_2CO_3	toluene	65	0
14	eosin Y	Cs_2CO_3	diglyme	65	0
15	eosin Y	Cs_2CO_3	MeOH	65	0
16[c]	eosin Y	Cs_2CO_3	DMA	65	0
17	–	Cs_2CO_3	DMA	65	0

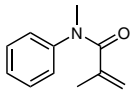
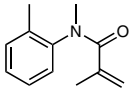
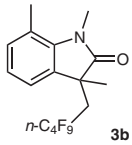
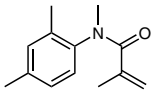
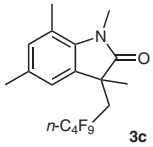
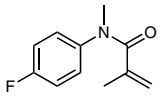
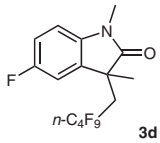
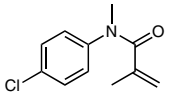
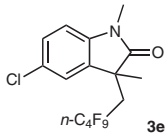
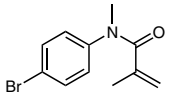
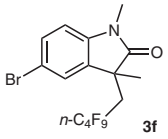
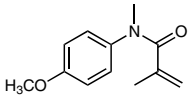
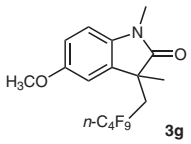
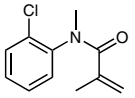
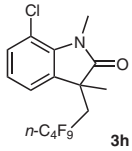
[a] Reaction conditions: **1a** (0.3 mmol), **2a** (0.9 mmol), base (0.3 mmol), catalyst (5 mmol %), solvent (0.2 M in substrate), 65 °C, 16 h, 26 W compact LED lightbulb.
[b] Isolated yield.
[c] No illumination.

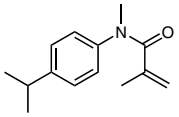
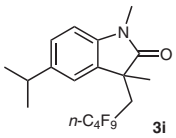
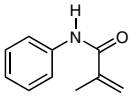
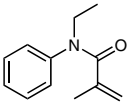
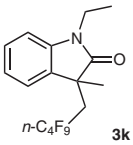
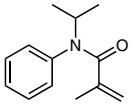
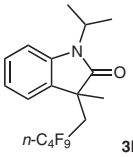
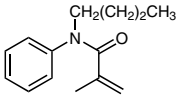
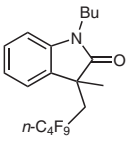
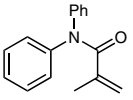
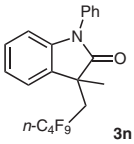
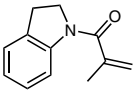
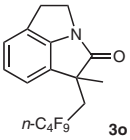
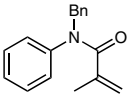
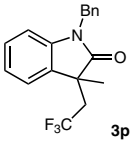
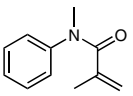
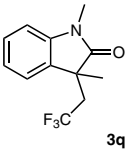
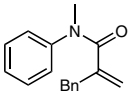
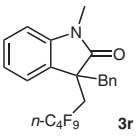
worked well to deliver the desired products **3k–p** in yields of 67–83% (entries 11–16). However, none of the desired product was obtained when an *N*-unprotected *N*-arylmethacrylamide was used (entry 10). Replacement of *n*-C_4F_9I with CF_3I, *n*-$C_6F_{13}I$, or *n*-$C_8F_{17}I$ afforded the corresponding products in yields of 58–88%. In addition, 2-benzyl-*N*-methyl-*N*-phenylacrylamide also reacted smoothly to deliver the corresponding oxindole **3q** in 66% yield (entry 17). It is interesting to observe that the reactions of R_FI with *N*-arylacrylamides containing two methyl groups on the double bond proceeded without any problem to generate the *anti*-isomers of the products with high stereoselectivity (dr > 20:1), albeit with a slightly inferior yields of less than 50% (entries 24–26). We tentatively assigned the major product as the *anti*-isomer on the basis of the NOESY spectra of **3x**.

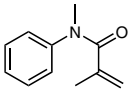
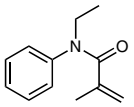
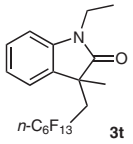
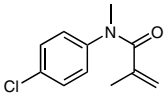
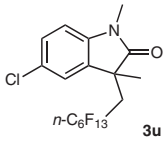
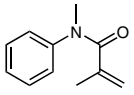
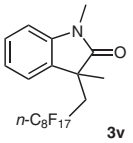
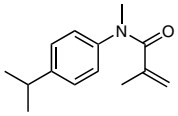
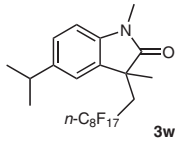
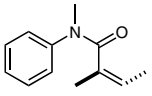
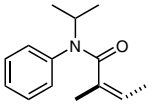
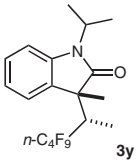
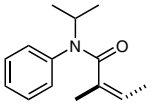
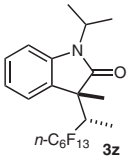
Table 2 Photocatalyzed Perfluoroalkylation/Cyclization of Arylacrylamides[a]



1 2 3

Entry	Arylacrylamide	R_FI	Products	Yield[b] (%)
1		*n*-C_4F_9I	 **3a**	85
2		*n*-C_4F_9I	 **3b**	75
3		*n*-C_4F_9I	 **3c**	72
4		*n*-C_4F_9I	 **3d**	65
5		*n*-C_4F_9I	 **3e**	77
6		*n*-C_4F_9I	 **3f**	82
7		*n*-C_4F_9I	 **3g**	61
8		*n*-C_4F_9I	 **3h**	80

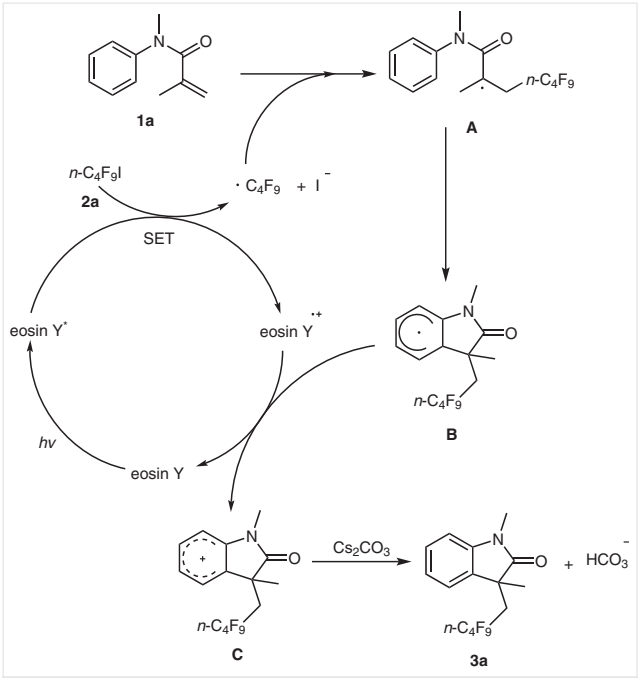
Entry	Arylacrylamide	R_FI	Products	Yield[b] (%)
9		*n*-C_4F_9I	 **3i**	76
10		*n*-C_4F_9I	–	0
11		*n*-C_4F_9I	 **3k**	71
12		*n*-C_4F_9I	 **3l**	80
13		*n*-C_4F_9I	 **3m**	83
14		*n*-C_4F_9I	 **3n**	67
15		*n*-C_4F_9I	 **3o**	73
16		CF_3I	 **3p**	64
17		CF_3I	 **3q**	58
18		*n*-C_4F_9I	 **3r**	66

Entry	Arylacrylamide	R_FI	Products	Yield[b] (%)
19		*n*-C_6F_{13}I	 **3s**	87
20		*n*-C_6F_{13}I	 **3t**	86
21		*n*-C_6F_{13}I	 **3u**	81
22		*n*-C_8F_{17}I	 **3v**	88
23		*n*-C_8F_{17}I	 **3w**	82
24		*n*-C_4F_9I	 **3x**	50
25		*n*-C_4F_9I	 **3y**	47
26		*n*-C_6F_{13}I	 **3z**	40

[a] Reaction conditions: **1** (0.3 mmol), **2** (0.9 mmol), base (0.3 mmol), eosin Y (5 mmol %), DMA (0.2 M in substrate), 65 °C, 16 h, 26 W compact LED lightbulb.
[b] Isolated yield.

To probe the mechanism of this transformation, we performed several control experiments under the optimized conditions. None of the desired product was detected when a stoichiometric amount of the radical scavenger TEMPO was added to the reaction mixture, suggesting that reaction is likely to involved a radical process. To determine whether the alkyl radical is formed directly from excited eosin Y or whether it is the related radical anion formed by reaction with the amide, DIPEA was treated with *n*-C_4F_9I under the optimized condition.[23] No perfluorobutylation of DIPEA was detected, showing that the alkyl radical is probably formed directly from excited eosin Y.

On the basis of reports in the literature,[4f,20,23] we propose a plausible mechanism for this transformation (Scheme 2). Eosin Y acts as a photoredox catalyst and, after its excitation with visible light, it transforms *n*-C_4F_9I (**2a**) into a perfluoroalkyl radical through single-electron transfer. Addition of this radical to the double bond of **1a** leads to the formation of a radical intermediate **A** which subsequently undergoes intramolecular cyclization to give radical intermediate **B**. Intermediate B provides an electron for the reductive quenching of the eosin Y radical cation and is oxidized in the process to give species **C**. Finally, **C** is transformed into the desired perfluoralkylated oxindole **3a** by reaction with the base.



Scheme 2 Proposed mechanism

In summary, we have developed a transition-metal-free method for the synthesis of perfluoroalkylated oxindoles from *N*-arylacrylamides and R_FI by using visible light as the reaction initiator.[24] Success of the reaction was critically dependent on the use of the inexpensive organic dye eosin Y as a photocatalyst. It is certain that this process shows considerable advantages in terms of the simplicity of the reaction procedure.

Funding Information

Funding Information: Joint Funds of the Department of Science of Guizhou Province for the Guizhou Institute of Technology, (Grant/Award Number: QKH20167093)

Acknowledgment

Yang would like to thank the Joint Funds of the Department of Science of Guizhou Province for the Guizhou Institute of Technology for financial support.

Supporting Information

Supporting information for this article is available online at https://doi.org/10.1055/s-0037-1611781.

Primary Data

for this article are available online at https://doi.org/10.1055/s-0037-1611781 and can be cited using the following DOI: 10.4125/pd0103th.

References and Notes

(1) (a) Chambers, R. D. *Fluorine in Organic Chemistry* 1973. (b) *Organofluorine Chemistry: Principles and Commercial Applications*; Banks, R. E.; Smart, B. E.; Tatlow, J. C., Ed.; Plenum Press: New York, **1994**. (c) Kirsch, P. *Modern Fluoroorganic Chemistry: Synthesis, Reactivity, Applications*; Wiley-VCH: Weinheim, **2004**.

(2) (a) Umemoto, T. *Chem. Rev.* **1996**, *96*, 1757. (b) Prakash, G. K. S.; Yudin, A. K. *Chem. Rev.* **1997**, *97*, 757. (c) Ma, J.-A.; Cahard, D. *Chem. Rev.* **2008**, *108*, PR1. (d) Kirk, K. L. *Org. Process Res. Dev.* **2008**, *12*, 305. (e) Purser, S.; Moore, P. R.; Swallow, S.; Gouverneur, V. *Chem. Soc. Rev.* **2008**, *37*, 320. (f) Ma, J.-A.; Cahard, D. *J. Fluorine Chem.* **2007**, *128*, 975. (g) Tomashenko, O. A.; Grushin, V. V. *Chem. Rev.* **2011**, *111*, 4475.

(3) (a) Chu, L.; Qing, F.-L. *J. Am. Chem. Soc.* **2010**, *132*, 7262. (b) Weng, Z.; Li, H.; He, W.; Yao, L.-F.; Tan, J.; Chen, J.; Yuan, Y.; Huang, K.-W. *Tetrahedron* **2012**, *68*, 2527. (c) Jiang, X.; Chu, L.; Qing, F.-L. *J. Org. Chem.* **2012**, *77*, 1251. (d) Luo, D.-F.; Xu, J.; Fu, Y.; Guo, Q.-X. *Tetrahedron Lett.* **2012**, *53*, 2769. (e) Herrmann, A. T.; Smith, L. L.; Zakarian, A. *J. Am. Chem. Soc.* **2012**, *134*, 6976. (f) Hu, B.; Bezpalko, M. W.; Fei, C.; Dickie, D. A.; Foxman, B. M.; Deng, L. *J. Am. Chem. Soc.* **2018**, *140*, 13913. (g) Hu, B.; Deng, L. *Angew. Chem. Int. Ed.* **2018**, *57*, 2233.

(4) (a) Bravo, A.; Bjørsvik, H.-R.; Fontana, F.; Liguori, L.; Mele, A.; Minisci, F. *J. Org. Chem.* **1997**, *62*, 7128. (b) Zhang, X.-G.; Dai, H.-X.; Wasa, M.; Yu, J.-Q. *J. Am. Chem. Soc.* **2012**, *134*, 11948. (c) Wang, X.; Truesdale, L.; Yu, J.-Q. *J. Am. Chem. Soc.* **2010**, *132*, 3648. (d) Loy, R. N.; Sanford, M. S. *Org. Lett.* **2011**, *13*, 2548. (e) Hafner, A.; Bihlmeier, A.; Nieger, M.; Klopper, W.; Bräse, S. *J. Org. Chem.* **2013**, *78*, 7938. (f) Chen, X.; Tan, Z.; Gui, Q.; Hu, L.; Liu, J.; Wu, J.; Wang, G. *Chem. Eur. J.* **2016**, *22*, 6218.

(5) (a) Xiao, J.-C.; Ye, C.; Shreeve, J. M. *Org. Lett.* **2005**, *7*, 1963. (b) Anton, L.; Vladimir, V. G. *J. Am. Chem. Soc.* **2007**, *135*, 12584. (c) Oishi, M.; Kondo, H.; Amii, H. *Chem. Commun.* **2009**, 1909. (d) Morimoto, H.; Tsubogo, T.; Litvinas, N. D.; Hartwig, J. F. *Angew. Chem. Int. Ed.* **2011**, *50*, 3793. (e) Popov, I.; Lindeman, S.; Daugulis, O. *J. Am. Chem. Soc.* **2011**, *133*, 9286.

(6) (a) Chu, L.; Qing, F.-L. *Org. Lett.* **2010**, *12*, 5060. (b) Senecal, T. D.; Parson, A. T.; Buchwald, S. *J. Org. Chem.* **2011**, *76*, 1174. (c) Qi, Q.; Shen, Q.; Lu, L. *J. Am. Chem. Soc.* **2012**, *134*, 6548. (d) Ye, Y.; Sanford, M. S. *J. Am. Chem. Soc.* **2012**, *134*, 9034. (e) Wu, L.; Wang, F.; Wan, X.; Wang, D.; Chen, P.; Liu, G. *J. Am. Chem. Soc.* **2017**, *139*, 2904.

(7) (a) Parsons, A. T.; Buchwald, S. L. *Angew. Chem. Int. Ed.* **2011**, *50*, 9120. (b) Wang, X.; Ye, Y.; Zhang, S.; Feng, J.; Xu, Y.; Zhang, Y.; Wang, J. *J. Am. Chem. Soc.* **2011**, *133*, 16410. (c) Chu, L.; Qing, F.-L. *Org. Lett.* **2012**, *14*, 2106. (d) He, Z.; Luo, T.; Hu, M.; Cao, Y.; Hu, J. *Angew. Chem. Int. Ed.* **2012**, *51*, 3944. (e) Yang, B.; Xu, X.-H.; Qing, F.-L. *Org. Lett.* **2016**, *18*, 5956. (f) Wang, F.; Wang, D.; Wan, X.; Wu, L.; Chen, P.; Liu, G. *J. Am. Chem. Soc.* **2016**, *138*, 15547.

(8) (a) Huang, W.-Y.; Hung, B.-N.; Hu, C.-M. *J. Fluorine Chem.* **1983**, *23*, 193. (b) Huang, W.-Y.; Wang, W.; Huang, B.-N. *Acta Chim. Sin. (Engl. Ed.)* **1985**, *43*, 409. (c) Huang, W.-Y.; Ma, W.; Chen, J.; Zhan, B. *Chin. J. Chem.* **1990**, *10*, 244. (d) Huang, B.-N.; Liu, J.-T.; Huang, W.-Y. *J. Chem. Soc., Chem. Commun.* **1990**, 1781. (e) Huang, B.-N.; Liu, J.-T.; Huang, W.-Y. *J. Chem. Soc., Perkin. Trans. 1* **1994**, 101. (f) Huang, W.-Y.; Ma, W.-P. *Chin. J. Chem.* **1992**, *10*, 180. (g) Huang, W.-Y.; Yu, H.-B. *Chin. Chem. Lett.* **1996**, *7*, 425.

(9) (a) Huang, B.-N.; Liu, J.-T. *Tetrahedron Lett.* **1990**, *31*, 2711. (b) Huang, B.-N.; Liu, J.-T. *J. Fluorine Chem.* **1993**, *64*, 37. (c) Wu, F.-H.; Huang, B.-N.; Lu, L.; Huang, W.-Y. *J. Fluorine Chem.* **1996**, *80*, 91. (d) Petrik, V.; Cahard, D. *Tetrahedron Lett.* **2007**, *48*, 3327. (e) Dmowski, W.; Piasecka-Maciejewska, K. *J. Fluorine Chem.* **2010**, *131*, 746. (f) Fang, X.; Ying, Q.; Chen, Y.; Yang, X.; Yang, X.; Wu, F. *J. Fluorine Chem.* **2008**, *129*, 280.

(10) (a) Matsui, M.; Shibata, K.; Muramatsu, H.; Sawada, H.; Nakayama, M. *Synlett* **1991**, 113. (b) Qiu, W.; Burton, D. J. *J. Fluorine Chem.* **1993**, *60*, 93. (c) Yajima, T.; Nagano, H. *Org. Lett.* **2007**, *9*, 2513. (d) Qi, Q.; Shen, Q.; Lu, L. *J. Fluorine Chem.* **2012**, *133*, 115. (e) Barata-Vallejo, S.; Postigo, A. *Eur. J. Org. Chem.* **2012**, 1889.

(11) (a) Nagib, D. A.; Scott, M. E.; MacMillan, D. W. C. *J. Am. Chem. Soc.* **2009**, *131*, 10875. (b) Pham, P. V.; Nagib, D. A.; MacMillan, D. W. C. *Angew. Chem. Int. Ed.* **2011**, *50*, 6119.

(12) (a) Neumann, M.; Füldner, S.; König, B.; Zeitler, K. *Angew. Chem. Int. Ed.* **2011**, *50*, 951. (b) Neumann, M.; Zeitler, K. *Org. Lett.* **2012**, *14*, 2658. (c) Hari, D. P.; Schroll, P.; König, B. *J. Am. Chem. Soc.* **2012**, *134*, 2958.

(13) (a) Zhang, Z.; Tang, X.; Dolbier, W. R. Jr. *Org. Lett.* **2015**, *17*, 4401. (b) Zhang, Z.; Martinez, H.; Dolbier, W. R. *J. Org. Chem.* **2017**, *82*, 2589.

(14) (a) Yu, W.; Xu, X.-H.; Qing, F.-L. *Org. Lett.* **2016**, *18*, 5130. (b) Lin, Q.-Y.; Ran, Y.; Xu, X.-H.; Qing, F.-L. *Org. Lett.* **2016**, *18*, 2419.

(15) (a) Li, L.; Huang, M.; Liu, C.; Xiao, J.-C.; Chen, Q.-Y.; Guo, Y.; Zhao, Z.-G. *Org. Lett.* **2015**, *17*, 4714. (b) Wu, X.; Meng, C.; Yuan, X.; Jia, X.; Qian, X.; Ye, J. *Chem. Commun.* **2015**, *51*, 11864. (c) Lefebvre, Q.; Hoffmann, N.; Rueping, M. *Chem. Commun.* **2016**, *52*, 2493.

(16) (a) Dounay, A. B.; Overman, L. E. *Chem. Rev.* **2003**, *103*, 2945. (b) Marti, C.; Carreira, E. M. *Eur. J. Org. Chem.* **2003**, 2209. (c) Zhou, F.; Liu, Y.-L.; Zhou, J. *Adv. Synth. Catal.* **2010**, *352*, 1381. (d) Rottmann, M.; McNamara, C.; Yeung, B. K. S.; Lee, M. C. S.; Zou, B.; Russell, B.; Seitz, P.; Plouffe, D. M.; Dharia, N. V.; Tan, J.; Cohen, S. B.; Spencer, K. R.; González-Páez, G. E.; Lakshminarayana, S. B.; Goh, A.; Suwanarusk, R.; Jegla, T.; Schmitt, E. K.; Beck, H.-P.; Brun, R.; Nosten, F.; Renia, L.; Dartois, V.; Keller, T. H.; Fidock, D. A.; Winzeler, E. A.; Diagana, T. T. *Science* **2010**, *329*, 1175.

(17) (a) Matcha, K.; Narayan, R.; Antonchick, A. P. *Angew. Chem. Int. Ed.* **2013**, *52*, 7985. (b) Meng, Y.; Guo, L.-N.; Wang, H.; Duan, X.-H. *Chem. Commun.* **2013**, *49*, 7540. (c) Fu, W.; Xu, F.; Fu, Y.; Zhu, M.; Zhou, D. *J. Org. Chem.* **2013**, *78*, 12202. (d) Wang, H.; Guo, L.-N.; Duan, X.-H. *Org. Lett.* **2013**, *15*, 5254. (e) Zhang, M.-Z.; Sheng, W.-B.; Jiang, Q.; Tian, M.; Yin, Y.; Guo, C.-C. *J. Org. Chem.* **2014**, *79*, 10829.

(18) (a) Zhao, Y.; Li, Z.; Sharma, U. K.; Sharma, N.; Song, G.; Van der Eycken, E. V. *Chem. Commun.* **2016**, *52*, 6395. (b) Jiang, Y.-Y.; Liang, S.; Zeng, C.-C.; Hu, L.-M.; Sun, B.-G. *Green Chem.* **2016**, *18*, 6311. (c) Yang, L.; Lu, W.; Zhou, W.; Zhang, F. *Green Chem.* **2016**, *18*, 2941. (d) Patel, P.; Borah, G. *Chem. Commun.* **2017**, *53*, 443. (e) Yu, L.-Z.; Wei, Y.; Shi, M. *Chem. Commun.* **2017**, *53*, 8980.

(19) (a) Yen, A.; Lautens, M. *Org. Lett.* **2018**, *20*, 4323. (b) Li, Y.; Wang, K.; Ping, Y.; Wang, Y.; Kong, W. *Org. Lett.* **2018**, *20*, 921. (c) Kilaru, P.; Acharya, S. P.; Zhao, P. *Chem. Commun.* **2018**, *54*, 924. (d) Wu, Z.-J.; Li, S.-R.; Long, H.; Xu, H.-C. *Chem. Commun.* **2018**, *54*, 4601.

(20) (a) Mu, X.; Wu, T.; Wang, H.-Y.; Guo, Y.-L.; Liu, G. *J. Am. Chem. Soc.* **2012**, *134*, 878. (b) Egami, H.; Shimizu, R.; Sodeoka, M. *J. Fluorine Chem.* **2013**, *152*, 51. (c) Kong, W.; Casimiro, M.; Merino, E.; Nevado, C. *J. Am. Chem. Soc.* **2013**, *135*, 14480. (d) Liu, J.; Zhuang, S.; Gui, Q.; Chen, X.; Yang, Z.; Tan, Z. *Eur. J. Org. Chem.* **2014**, *2014*, 3196. (e) Wang, J.-Y.; Su, Y.-M.; Yin, F.; Bao, Y.; Zhang, X.; Xu, Y.-M.; Wang, X.-S. *Chem. Commun.* **2014**, *50*, 4108.

(21) (a) Tang, S.; Li, Z.-H.; Wang, M.-W.; Lia, Z.-P.; Sheng, R.-L. *Org. Biomol. Chem.* **2015**, *13*, 5285. (b) Mai, W.-P.; Sun, B.; Qian, G.-S.; Yuan, J.-W.; Mao, P.; Yang, L.-R.; Xiao, Y.-M. *Tetrahedron* **2015**, *71*, 8416. (c) Wang, H.; Guo, L.-N.; Duan, X.-H. *J. Org. Chem.* **2016**, *81*, 860.

(22) (a) Ji, P.-Y.; Zhang, M.-Z.; Xu, J.-W.; Liu, Y.-F. Guo C.-C. *J. Org. Chem.* **2016**, *81*, 5181. (b) Guo, J.-Y.; Wu, R.-X.; Jin, J.-K.; Tian, S.-K. *Org. Lett.* **2016**, *18*, 3850. (c) Liu, F.; Li, P. *J. Org. Chem.* **2016**, *81*, 6972. (d) Li, C.-X.; Tu, D.-S.; Yao, R.; Yan, H.; Lu, C.-S. *Org. Lett.* **2016**, *18*, 4928.

(23) Srivastavaa, V.; Singh, P. P. *RSC Adv.* **2017**, *7*, 31377.

(24) (a) **Organocatalyzed Photoredox Perfluoroalkylation/Cyclization of *N*-Arylacrylamides Perfluoroalkyl Iodides; General Procedure**

A 25 mL tube was charged with the appropriate *N*-arylacrylamide **1** (0.3 mmol), R_FI **2** (0.9 mmol), Cs_2CO_3 (0.3 mmol), and eosin Y (5% mmol). DMA (2 mL) was added and the tube was purged with argon. The mixture was stirred and irradiated with a 26 W compact LED lightbulb at 65 °C for 16 h until the reaction was completed. H_2O (10 mL) and CH_2Cl_2 (10 mL) were added successively to the cooled reaction mixture, the organic phase was separated, and the aqueous phase was further extracted with CH_2Cl_2 (3 × 30 mL). The combined organic layers were dried (Mg_2SO_4) and concentrated under vacuum. The residue was purified performed by flash column chromatography (silica gel).

1,3-Dimethyl-3-(2,2,3,3,4,4,5,5,5-nonafluoropentyl)-1,3-dihydro-2*H*-indol-2-one (3a)

Isolated by flash column chromatography [silica gel, PE–EtOAc (50:1)] as a yellow oil; yield: 100 mg (85%). IR (neat): 2979, 1719, 1619, 1470, 1126, 947 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ = 1.44 (s, 3 H), 2.54–2.68 (m, 1 H), 2.83–2.95 (m, 1 H), 3.25 (s, 3 H), 6.89 (d, *J* = 8.0 Hz, 1 H), 7.09 (t, *J* = 7.6 Hz, 1 H), 7.28 (d, *J* = 7.6 Hz, 1 H), 7.32 (t, *J* = 8.0 Hz, 1 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 25.8, 26.4, 26.5, 36.9 (t, *J* = 20.1 Hz), 44.1 (d, *J* = 1.8 Hz), 108.4, 122.6, 123.1, 123.4, 123.5, 128.5, 128.8, 131.2, 142.8, 178.5.^{19}F NMR (376 MHz, $CDCl_3$): δ = –125.64 to –125.42 (m, 2 F), –124.21 (d, *J* = 9.4 Hz, 2 F), –114.68 to –113.84 (m, 1 F), –108.96 to –108.16 (m, 1 F), –80.76 (t, *J* = 9.4 Hz, 3 F). HRMS (ESI): *m/z* [M^+] calcd for $C_{15}H_{12}F_9NO$: 393.0775; found: 393.0778.

1,3,7-Trimethyl-3-(2,2,3,3,4,4,5,5,5-nonafluoropentyl)-1,3-dihydro-2*H*-indol-2-one (3b)

Isolated by flash column chromatography [silica gel, PE–EtOAc (50:1)] as a yellow oil; yield: 91 mg (75%). IR (neat): 2918, 1722, 1621, 1410, 1145, 670 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ = 1.40 (s, 3 H), 2.60 (s, 3 H), 2.50–2.63 (m, 1 H), 2.82–2.95 (m, 1 H), 3.53 (s, 3 H), 6.97 (t, *J* = 7.6 Hz, 1 H), 7.04 (d, *J* = 7.2 Hz, 1 H), 7.10 (d, *J* = 6.8 Hz, 1 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 19.1, 26.4, 29.9, 37.1 (t, *J* = 20.3 Hz), 44.5 (d, *J* = 1.9 Hz), 120.1, 121.3, 121.4 (2 C), 122.5, 131.9, 132.2 (2 C), 140.6, 179.3. ^{19}F NMR (376 MHz, $CDCl_3$): δ = –125.71 to –125.50 (m, 2 F), –124.27 (d, *J* = 9.8 Hz, 2 F), –114.03 to –113.94 (m, 1 F), –109.01 to –108.24 (m, 1 F), –80.86 to –80.79 (m, 3 F). HRMS (ESI): *m/z* [M^+] calcd for $C_{16}H_{14}F_9NO$: 407.0932; found: 407.0931.