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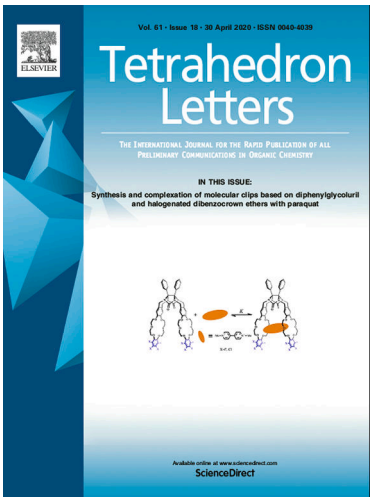

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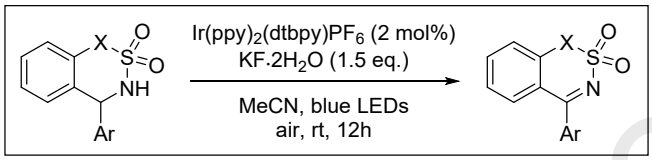

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Efficient visible-light photocatalytic aerobic oxidation of cyclic sulfamides to imines

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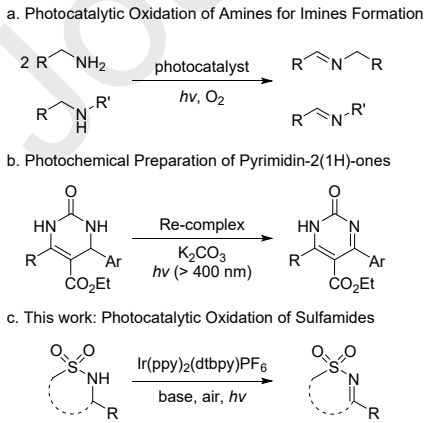
ABSTRACT

A highly efficient photocatalytic aerobic oxidation of cyclic sulfamides to synthesize cyclic N-sulfonyl imines with $Ir(ppy)_2(dtbpy)PF_6$ as photocatalyst is reported. These environmentally friendly transformations exihibit good to excellent isolated yields and good generality with respect to both five-membered and six-membered cyclic sulfamides.

As an important class of versatile building blocks, the cyclic imines are often used for the synthesis of drugs and various pharmacologically relevant compounds.[1] Recently, cyclic *N*-sulfonyl imines have attracted great attention, owing to their high reactivity and enantioselectivity in various asymmetric transformations, particularly in arylation reaction.[2] Except for the direct condensation of sulfamides and aldehydes/ketones, the oxidative dehydrogenation of sulfamides by using stoichiometric amounts of metal salts or organic peroxides as oxidants also is an alternative approach to generate the corresponding sulfonyl imines.[3] Normally, excess of oxidants and the harmful waste byproducts in this process are unavoidable, which led to tedious purification workup. Given the pivotal role of cyclic sulfonyl imines in synthetic chemistry,[4] to devote much effort to develop an effective, atom-economical and environmentally benign approach to this kind of structural motif is still important and desirable.



Scheme 1. Photocatalytic oxidation of amines to prepare imines.

In the past decade, visible-light-driven photocatalysis has evolved into a powerful method for organic transformations.[5] Irradiation of visible-light generates an excited photocatalyst that can then undergo a reductive quenching via a single-electron transfer (SET) from an electron donor. When using a tertiary amine as the electron donor, the resulting *N*-centered radical cation can ultimately form an electrophilic iminium cation. Capturing this active species with a range of different nucleophiles provides a powerful method to α-functionalizing a tertiary amine.[6] Moreover, the oxidation of primary or secondary amine to prepare imines under visible-light and oxygen atmosphere has been well developed by employing semiconductors,[7] homogeneous organic dye[8] and metal complexes[9] as photocatalysts (a, Scheme 1). In sharp contrast, there are only limited reports on photocatalytic directly oxidizing amides to the corresponding *N*-sulfonyl imines. In 2011, Wu reported a Re(I)-catalytic photochemical conversion from 3,4-dihydropyrimidin-2(1*H*)-ones (DHPMs) to pyrimidin-2(1*H*)-ones upon visible light irradiation in the presence of K_2CO_3 and CCl_4(b, Scheme 1).[10] A direct SET from DHPMs to Re(I) complex followed by deprotonation can occur to form a DHPMs radical due to powerful redox potential of the excited Re(I) complex. The further extraction of a hydrogen atom by the CCl_3• radical generated in situ completes the whole process to form pyrimidin-2(1*H*)-ones. Very recently, the visible-light-driven oxidative activation of amide *N*-H bond to generate *N*-centered radical for synthetic applications has been successfully achieved by several research groups employing proton-coupled electron transfer (PCET)[11] and oxidative deprotonation electron transfer (ODET)[12] strategy, respectively. Considering the significance of *N*-sulfonyl imine in synthetic chemistry, these progresses inspired us to investigate the feasibility of photocatalytic oxidation of sulfamide to prepare the corresponding *N*-sulfonyl imines. Herein, we report the concise and visible-light photocatalytic aerobic oxidation of cyclic sulfamides for the efficient synthesis of cyclic *N*-sulfonyl imines, using $Ir(ppy)_2(dtbpy)PF_6$ as photoredox catalyst under mild condition (c, Scheme 1).

We chose cyclic sulfamides **1a** as the model substrate for initial investigation. By subjecting to irradiation with a 12-W

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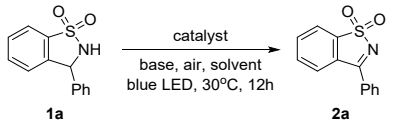
found to be converted to imine with 2 mol% $Ir(ppy)_2(dtbpy)PF_6$ as photocatalyst and DCM as solvent (Table 1, entry 1). To our delight, the yield increased to 55% when KF • $2H_2O$ was added as a base (Table 1, entry 2). Then, a survey of various polar aprotic solvents such as EA, THF, DMA and MeCN were conducted to examine the reaction (Table 1, entries 3-6). MeCN proved to be the most suitable solvent for this transformation as the imine was obtained in 98% yield. Further investigation of base revealed that other inorganic base or organic base would dramatically reduce the yield (Table 1, entries 7-9). Moreover, control experiments showed that the photocatalyst, base, air and light are all essential for the desired reaction to proceed (Table 1, entries 10-12).

Table 1. Condition optimization



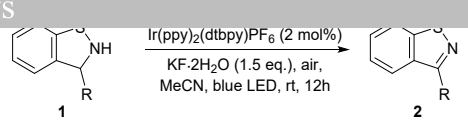
1a **2a**

Entry	Catalyst (2.0 mol%)	Oxidant	Base (1.5 eq.)	Solvent	Yield[a][%]
1	$Ir(ppy)_2(dtbpy)PF_6$	air	none	DCM	4%
2	$Ir(ppy)_2(dtbpy)PF_6$	air	$KF{\cdot}2H_2O$	DCM	55%
3	$Ir(ppy)_2(dtbpy)PF_6$	air	$KF{\cdot}2H_2O$	EA	45%
4	$Ir(ppy)_2(dtbpy)PF_6$	air	$KF{\cdot}2H_2O$	THF	45%
5	$Ir(ppy)_2(dtbpy)PF_6$	air	$KF{\cdot}2H_2O$	DMA	ND
6	$Ir(ppy)_2(dtbpy)PF_6$	air	$KF{\cdot}2H_2O$	MeCN	98%
7	$Ir(ppy)_2(dtbpy)PF_6$	air	Cs_2CO_3	MeCN	61%
8	$Ir(ppy)_2(dtbpy)PF_6$	air	KOH	MeCN	41%
9	$Ir(ppy)_2(dtbpy)PF_6$	air	DBU	MeCN	41%
10	none	air	$KF{\cdot}2H_2O$	MeCN	ND
11	$Ir(ppy)_2(dtbpy)PF_6$	none (in N_2)	$KF{\cdot}2H_2O$	MeCN	ND
12[b]	$Ir(ppy)_2(dtbpy)PF_6$	air	$KF{\cdot}2H_2O$	MeCN	ND

[a] Yield of the isolated product.
[b] Reaction was carried out in the dark.

With the best reaction conditions for the photocatalytic oxidations reactions established, the scope of the five-membered cyclic sulfonamides was investigated. As shown in Table 2, the cyclic sulfonamides bearing ortho-, meta-, and para-methyl phenyl ring provided the desired products in excellent yields (Table 2, entries 2-4). These results suggest that steric effects on the phenyl ring only slightly affect the reactivity. Significant electronic variation in the aryl groups can be well tolerated under this condition, the oxidation of all the aryl-substituted substrates occurred smoothly. Although the electron-rich derivatives with methoxy and tert-butyl substituting in phenyl ring were successful substrate, the yields diminished in somewhat (Table 2, entries 5-7). Compared to electron-rich derivatives, the substrates bearing chloro or fluro substituted aryl gave the oxidation products in better yields (Table 2, entries 8-10). Unfortunately, 3-methyl substituted substrate **1k** did not undergo oxidation reaction (Table 2, entry 11), as this may be due to the formed free radical intermediate is unstable enough to further oxidative dehydrogenation.

Table 2. Substrate scope of five-membered cyclic sulfonamides



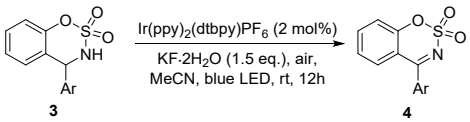
1 **2**

Entry	R	Yield[a][%]
1	Ph	98 (**2a**)
2	2-Me−C_6H_4	94 (**2b**)
3	3-Me−C_6H_4	96 (**2c**)
4	4-Me−C_6H_4	94 (**2d**)
5	2-MeO−C_6H_4	69 (**2e**)
6	3,5-MeO−C_6H_3	87 (**2f**)
7	4-^{t}Bu−C_6H_4	68 (**2g**)
8	3-Cl−C_6H_4	96 (**2h**)
9	4-Cl−C_6H_4	86 (**2i**)
10	4-F−C_6H_4	98 (**2j**)
11	Me	trace (**2k**)

[a] Yield of the isolated product.

To further determine the substrate generality of this protocol, we turned our attention to assessing the scope of six-membered cyclic sulfonamides **3** in the transformation and the results are summarized in Table 3. We observed the similar phenomena with five-membered cyclic sulfonamides **1**. A broad functional group tolerance in phenyl ring was also demonstrated in this reaction. Both the electron-rich and electron-deficient aryl-substituted sulfonamides delivered good yields, but substituting position seemed to influence the reaction outcome. Substituted group at ortho-position of the aryl ring had a negative impact on the yield (Table 3, entry 2 and 5). We guess that a potential 1,5-H shift pathway via six-membered transition state from the ortho-methyl to *N*-radical might result a reduced yield.

Table 3. Substrate scope of six-membered cyclic sulfonamides



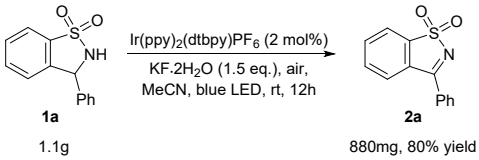
3 **4**

Entry	Ar	Yield[a][%]
1	Ph	96 (**4a**)
2	2-Me−C_6H_4	78 (**4b**)
3	3-Me−C_6H_4	96 (**4c**)
4	4-Me−C_6H_4	98 (**4d**)
5	2-MeO−C_6H_4	69 (**4e**)
6	3,5-MeO−C_6H_3	86 (**4f**)
7	4-^{t}Bu−C_6H_4	89 (**4g**)
8	3-Cl−C_6H_4	95 (**4h**)
9	4-Cl−C_6H_4	95 (**4i**)
10	4-F−C_6H_4	87 (**4j**)

[a] Yield of the isolated product.

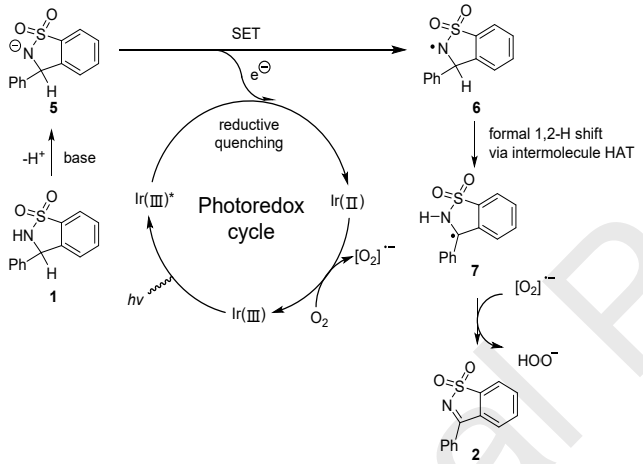
To further highlight the practical application of the current method, 3-phenyl-2, 3-dihydrobenzo[*d*]isothiazole 1,1-dioxides **1a** was performed under the optimal condition on a gram scale.

As i B. was obtained with 80% isolated yield.



Scheme 2. Gram scale experiment.

Based on the control experiments (Table 1, entries 10-12) and the related literatures, a plausible mechanism is proposed in Scheme 3. First, the sulfonamide **1** is deprotonated to form a sulfonamide anion **5** under a base. Irradiation with visible light generates an excited state Ir(III)*. The excited Ir(III)* is then reductively quenched via a single electron transfer from anion **5** to produce Ir(II) and sulfonamide *N*-radical cation **6**. After a formal 1,2-H shift via intermolecular HAT [13], a benzylic free radical **7** is formed. In the presence of oxygen, electron is transferred from Ir(II) to molecular oxygen, which in turn produces superoxide anion radical O_2•− and regenerate Ir(III) species. At last, the cyclic radical **7** lost an electron and a proton to produce the final oxidation product **2**.



Scheme 3. Proposed mechanism of the photocatalyzed aerobic oxidation

To summarize, using $Ir(ppy)_2(dtbpy)PF_6$ as catalyst, we have achieved a photochemical approach to access cyclosulfonimide. Two kinds of cyclic sulfonamides can be successfully converted to the corresponding N-sulfonyl imine product with good to excellent yields at room temperature, and the whole process is environmentally benign. Efforts toward further mechanistic understanding and extension of this oxidative dehydrogenation process are currently underway.

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References and notes

1 (*a*)Singh, S. K.; Reddy, P. G.; Rao, K. S.; Lohray, B. B.; Misra, P.; Rajjak, S. A.; Rao, Y. K.; Venkateswarlu, A. *Bioorg. Med. Chem. Lett.* **2004,** *14*, 499–504; (*b*) Saha, D.; Bagchi, S.; Sharma, A. *Chem. Heterocycl. Compd.* **2018** *54*, 302–313; (*c*) Debnath, S.; Mondal, S. *Eur. J. Org. Chem.* **2018,** *2018*, 933–956.

2 (*a*) Nishimura, T.; Noishiki, A.; Tsui, G. C.; Hayashi, T. *J. Am. Chem. Soc.* **2012,** *134*, 5056–5059; (*b*) Wang, H.; Jiang, T.; Xu, M. H. *J. Angew. Chem. Int. Ed.* **2013,** *52*, 7540–7544; (*d*) Zhou, B.; Li, K. Z.; Jiang, C. H.; Lu, Y. X.; Hayashi, T. *Adv. Synth. Catal.* **2017,** *359*, 1969–1975.

3 (*a*) Aoyama, T.; Sonoda, N.; Yamauchi, M.; Toriyama, K.; Anzai, M.; Ando, A.; Shioiri, T. *Synlett* **1998,** 35–36; (*b*) Davis, B. G.; Maughan, M. A.; Chapman, T. M.; Villard, R.; Courtney, S. *Org. Lett.* **2002,** *4*, 103–106; (*c*) Li, C. J.; Li, Z. P., *Pure Appl. Chem.* **2006,** *78*, 935–945; (*d*) Li, W. X.; Gan, J. H.; Fan, R. H. *Tetrahedron Lett.* **2010,** *51*, 4275–4277.

4 (*a*) Yu, C. B.; Wang, D. W.; Zhou, Y. G. *J. Org. Chem.* **2009,** *74*, 5633–5635; (*b*) Chen, F.; Li, Z. W.; He, Y. M.; Fan, Q. H. *Chin. J. Chem.* **2010,** *28*, 1529–1532; (*c*) Zhu, B. H.; Zheng, J. C.; Yu, C. B.; Sun, X. L.; Zhou, Y. G.; Shen, Q.; Tang, Y. *Org. Lett.* **2010,** *12*, 504–507; (*d*) Feng, X.; Zhou, Z.; Ma, C.; Yin, X.; Li, R.; Dong, L.; Chen, Y. C. *Angew. Chem. Int. Ed.* **2013,** *52*, 14173–14176; (*e*) Gu, J.; Ma, C.; Li, Q. Z.; Du, W.; Chen, Y. C. *Org. Lett.* **2014,** *16*, 3986–3989.

5 (*a*) Marzo, L.; Pagire, S. K.; Reiser, O.; König, B. *Angew. Chem. Int. Ed.* **2018,** *57*, 10034–10072; (*b*) Zhang, X.; Rakesh, K. P.; Ravindar, L.; Qin, H. L., *Green Chem.* **2018**, *20*, 4790-4833.(c) Yan, D. -M.; Zhao, Q.-Q.; Rao, L.; Chen, J.-R.; Xiao, W.-J., *Chem. Eur. J.* **2018**, *24*, 16895-16901.

6 (*a*) Condie, A. G.; Gonzalez-Gomez, J. C.; Stephenson, C. R. *J. Am. Chem. Soc.* **2010,** *132*, 1464–1465; (*b*) Hari, D. P.; König, B. *Org. Lett.* **2011,** *13*, 3852–3855; (*c*) Rueping, M.; Koenigs, R. M.; Poscharny, K.; Fabry, D. C.; Leonori, D.; Vila, C. *Chem. Eur. J.* **2012,** *18*, 5170–5174; (*d*) Wang, Z. Q.; Hu, M.; Huang, X. C.; Gong, L. B.; Xie, Y. X.; Li, J. H. *J. Org. Chem.* **2012,** *77*, 8705−8711; (*e*) Zhu, S. Q.; Rueping, M. *Chem. Commun.* **2012,** *48*, 11960–11962.

7 (*a*) Furukawa, S.; Ohno, Y.; Shishido, T.; Teramura, K.; Tanaka, T. *ACS Catal.* **2011,** *1*, 1150–1153; (*b*) Naya, S.; Kimura, K.; Tada, H. *ACS Catal.* **2012,** *3*, 10–13; (*c*) Yang, X. J.; Chen, B.; Li, X. B.; Zheng, L. Q.; Wu, L. Z.; Tung, C. H. *Chem. Commun.* **2014,** *50*, 6664–6667.

8 (*a*) Jiang, G.; Chen, J.; Huang, J. S.; Che, C. M. *Org. Lett.* **2009,** *11*, 4568–4571; (*b*) Berlicka, A.; König, B. *Photochem. Photobiol. Sci.* **2010,** *9*, 1359–1366; (*c*) Park, J. H.; Ko, K. C.; Kim, E.; Park, N.; Ko, J. H.; Ryu, D. H.; Ahn, T. K.; Lee, J. Y.; Son, S. U. *Org. Lett.* **2012,** *14*, 5502–5505.

9 (*a*) Largeron, M.; Fleury, M. B. *Angew. Chem. Int. Ed.* **2012,** *51*, 5409–5412; (*b*) Jawale, D. V.; Gravel, E.; Villemin, E.; Shah, N.; Geertsen, V.; Namboothiri, I. N.; Doris, E. *Chem. Commun.* **2014,** *50*, 15251–15254 ; (*c*) Largeron, M.; Fleury, M. B. *Chem. Eur. J.* **2015,** *21*, 3815–3820.

10 Liu, Q.; Li, Y. N.; Zhang, H. H.; Chen, B.; Tung, C. H.; Wu, L. Z. *J. Org. Chem.* **2011,** *76*, 1444–1447.

11 (*a*) Miller, D. C.; Choi, G. J.; Orbe, H. S.; Knowles, R. R. *J. Am. Chem. Soc.* **2015,** *137*, 13492–13495; (*b*) Choi, G. J.; Knowles, R. R. *J. Am. Chem. Soc.* **2015,** *137*, 9226–9229; (*c*) Gentry, E. C.; Knowles, R. R. *Acc. Chem. Res.* **2016,** *49*, 1546–1556.

12 (*a*) Chen, J. R.; Hu, X. Q.; Lu, L. Q.; Xiao, W. J. *Acc. Chem. Res.* **2016,** *49*, 1911–1923; (*b*) Zhao, Q. Q.; Chen, J.; Yan, D. M.; Chen, J. R.; Xiao, W. J. *Org. Lett.* **2017,** *19*, 3620–3623; (*c*) Chen, J.; Guo, H. M.; Zhao, Q. Q.; Chen, J. R.; Xiao, W. J. *Chem. Commun.* **2018,** *54*, 6780–6783.

13 Karmakar, S.; Datta, A. *Angew. Chem. Int. Ed.* **2014**, *53*, 9587-9591.

Highlights

- Convenient synthesis of cyclic *N*-sulfonyl imines from sulfamides
- Visible-light-driven photocatalytic aerobic oxidation under mild condition
- Environmentally benign oxidation process without stoichiometric chemical oxidants