Photoredox Catalysis

How to cite:
International Edition: doi.org/10.1002/anie.202107080
German Edition: doi.org/10.1002/ange.202107080

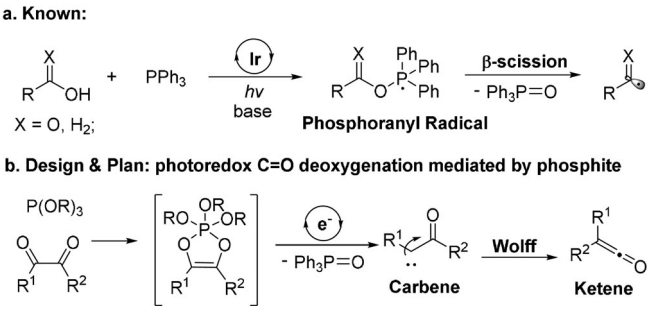
Photoredox Catalytic Phosphite-Mediated Deoxygenation of α-Diketones Enables Wolff Rearrangement and Staudinger Synthesis of β-Lactams

Hui Yang[+], Haijun Li[+], Guo Wei, and Zhiyong Jiang**

Abstract: *A novel visible-light-driven catalytic activation of C=O bonds by exploiting the photoredox chemistry of 1,3,2-dioxaphospholes, readily accessible from α-diketones and trialkyl phosphites, is reported. This mild and environmentally friendly strategy provides an unprecedented and efficient access to the Wolff rearrangement reaction which traditionally entails α-diazoketones as precursors. The resulting ketenes could be precisely trapped by alcohols/thiols to give α-aryl (thio)acetates and by imines to afford the valuable β-lactams in up to 99 % yields.*

Chemoselective deoxgenation of carbon–oxygen bonds represents one of the fundamental transformations in organic chemistry.[1] In particular, the reductive deoxygenation of ketones has attracted increasing attention of researchers owing to its wide application in the synthesis of bioactive natural products[2] and in processes for the transformation of petroleum and biomass feedstocks.[1,3] However, the direct activation of C=O bonds is particularly difficult due to their strong bond strength and high redox potentials. Modern hydrodeoxygenation transformations both in the laboratory and on industrial scales are still highly dependent on the classical Clemmensen (Zn/Hg, HCl)[4] and Wolff–Kishner methods,[5] demanding fierce conditions which lead to functional group compatibility problems.

Visible-light-driven photoredox catalysis is a powerful tool revitalized in recent years for the activation of covalent bonds, featuring intrinsic mildness and unparalleled reactivity that is usually difficult or impossible to access by other means.[6] Direct photoredox cleavage of C–O single bonds has already been realized by exploring the β-fission chemistry of phosphoranyl radicals.[7] In 2018, the Zhu group reported a novel activation platform for C–O bonds of carboxylic acids, yielding a green procedure for the synthesis of ketones directly from the abundant acids and alkenes (Scheme 1 a).[7c] Doyle and co-workers disclosed their work for the photocatalytic hydrodeoxygenation of not only carboxylic acids but also alcohols adopting essentially the same strategy.[7d] However, to the best of our knowledge, the direct deoxygenation of C=O bonds has never been achieved with photoredox catalysis.



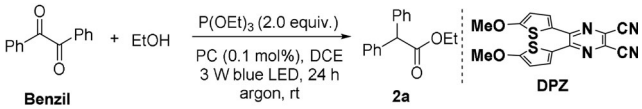
Scheme 1. Photocatalytic C–O bond activation.

Our group has a lasting interest in developing innovative photocatalytic methodologies, among which we paid special attention to the transformations of ketones.[8] By drawing inspiration from the phosphine-mediated C–O bond activation strategy, we imagined that photoredox-catalyzed fragmentation of 1,3,2-dioxaphospholes, the penta-coordinated oxyphosphoranes readily accessible from the reaction of α-diketones with phosphites,[9] would be a possible way of direct reductive deoxygenation of ketones (Scheme 1 b). We present herein our work along this line, which yielded a photoredox catalytic manifold for the direct synthesis of ketenes from activated ketones via formal Wolff rearrangement.[10] The strategy was further adapted for the direct preparation of β-lactams[11] (Staudinger reaction),[12] important core structures of antibiotic drugs and natural bioactive molecules.[13]

We began our investigation with benzil and triethyl phosphite as the model substrate and the deoxygenation reagent, respectively. With the irradiation of a 3 W blue LED (450 nm) and the catalysis of a dicyanopyrazine derived chromophore (DPZ) photosensitizer,[8,14] benzil underwent swift deoxygenation and Wolff rearrangement, affording a ketene intermediate which was trapped by ethanol (Table 1). Under optimized conditions, α,α-diphenylacetate **2a** was obtained in excellent yield (90 %, entry 6). When polar solvents such as THF or DMF were used, the yields dropped

[*] H. Li,[+] Dr. G. Wei, Prof. Dr. Z. Jiang
Key Laboratory of Natural Medicine and Immune Engineering of Henan Province, Henan University
Jinming Campus, Kaifeng, Henan, 475004 (P. R. China)
E-mail: weiguo0325@henu.edu.cn
chmjzy@henu.edu.cn
Prof. Dr. Z. Jiang
School of Chemistry and Chemical Engineering, Henan Normal University
Xinxiang, Henan, 453007 (P. R. China)
Dr. H. Yang[+]
School of Pharmacy, Henan University
Jinming Campus, Kaifeng, Henan, 475004 (P. R. China)
[+] These authors contributed equally to this work.
Supporting information and the ORCID identification number(s) for the author(s) of this article can be found under: https://doi.org/10.1002/anie.202107080.

Table 1: Optimization of the reaction conditions.[a]



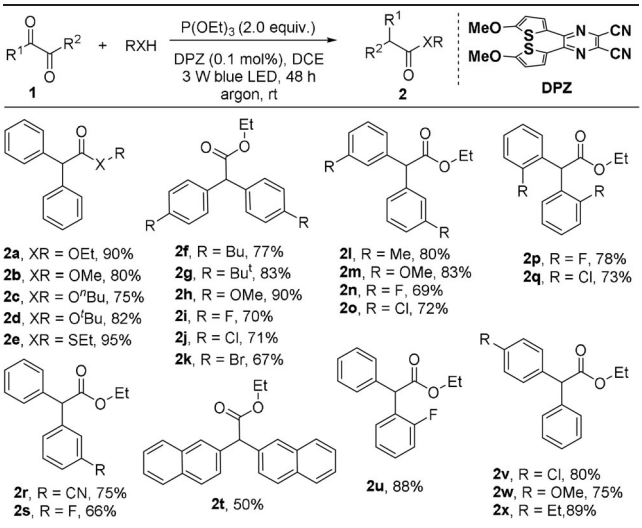
Entry	Photocatalyst [*x* mol%]	Solvent	Yield [%][b]
1	DPZ [0.1 mol%]	toluene	22
2	DPZ [0.1 mol%]	THF	15
3	DPZ [0.1 mol%]	DMF	N.D.
4	DPZ [0.1 mol%]	MeCN	70
5	DPZ [0.1 mol%]	DCE	53
6[c]	DPZ [0.1 mol%]	DCE	90
7[d]	DPZ [0.1 mol%]	DCE	N.D.
8	–	DCE	N.D.
9	$[Ru(bpy)_3][PF_6]_2$ [1.0 mol%]	DCE	34
10	$[Ir(dtbbpy)(ppy)_2][PF_6]$ [1.0 mol%]	DCE	38
11	Methylene Blue [1.0 mol%]	DCE	12
12	Eosin Y [1.0 mol%]	DCE	5

[a] Reaction conditions: benzil **1a** (0.1 mmol), $P(OEt)_3$ (0.2 mmol), EtOH (0.2 mmol), DPZ (0.1 mol%), solvent (1.0 mL), under argon protection, 3 W blue LED, 24 h, rt. [b] Determined by crude NMR with mesitylene as the internal standard. [c] Reaction time was extended to 48 h. [d] In the dark. DCE = dichloroethane. DMF = N,N-dimethylformamide. N.D. = not detected.

dramatically (entries 2 and 3). Other transition-metal or organic photosensitizers turned out to be less effective, even with a tenfold increase of the catalyst loading (entries 9–12). It is noteworthy that when the reaction was performed in the absence of photocatalyst or in the dark, **2a** could not be observed, thus underlining a photocatalyzed transformation.

With the optimal reaction conditions in hand, we explored the substrate scope for this Wolff rearrangement-enabled synthesis of 2-aryl acetates. As can be seen from Table 2, this method could be readily applied to the preparation of different alkyl esters by using the corresponding alcohols (**2a**–**2d**). Thioester **2e** could be obtained in even better yield

Table 2: Substrate scope for the synthesis of 2-aryl (thio)acetates.[a]

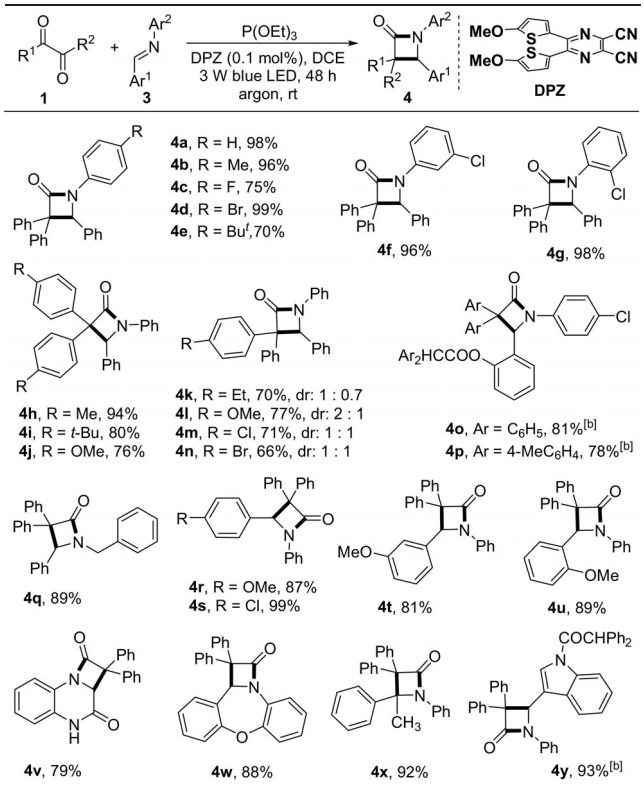


[a] Reaction conditions: α-diketone **1** (0.1 mmol), ROH (0.2 mmol), $P(OEt)_3$ (0.2 mmol), DPZ (0.1 mol%), DCE (1.0 mL), degassed with argon by three freeze–pump–thaw cycles, 3 W blue LED, 48 h, rt.

(95%) possibly due to the added nucleophilicity of ethanethiol. Both electron-donating (**2f**–**2h**, **2l**, **2m**, **2w**, **2x**) and electron-withdrawing (**2i**–**2k**, **2n**–**2s**, **2u**, **2v**) substituents on the phenyl rings could be well tolerated regardless of whether the ketone substrates are symmetrical or not. Electron-donating groups promoted Wolff rearrangement efficiently, while substrates with electron-withdrawing groups on the phenyl ring usually gave slightly lower yields, reflecting their different substituent effect on the migratory aptitude of the phenyl ring. When two phenyl groups of benzil were replaced by 2-naphthyl, reaction also worked effectively, furnishing product **2t** [U1] in 50% yield. Less successful or failed substrates for this transformation afforded a substantial amount of α-alkoxy ketones and α-benzyl ketones, originating from the O–H bond insertion and H abstraction of the carbene intermediates, respectively, as has already been well documented.[10]

The Staudinger synthesis of β-lactams[11] from ketenes by [2+2] cycloaddition with imines represents one of the most practical strategies to date. To our delight, under slightly modified conditions, our phosphite-mediated generation of ketenes could be efficiently merged with the Staudinger reaction (Table 3). When *N*-phenyl imine **3**, instead of alcohol, was added to the stirred solution of benzil and triethyl phosphite, the cycloaddition product β-lactam **4a** was

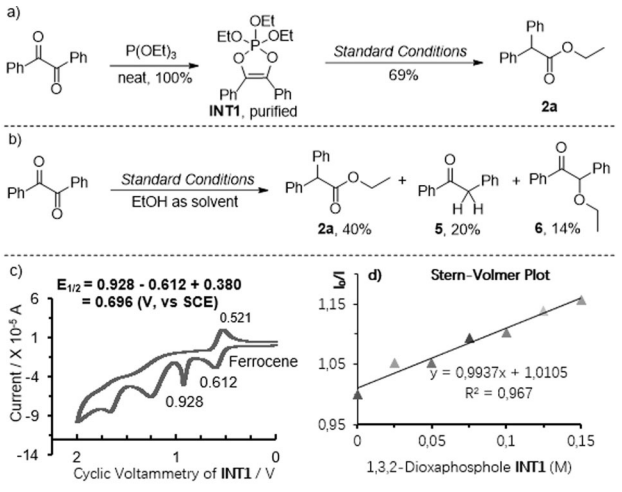
Table 3: Visible-light-promoted Staudinger synthesis of β-lactams from α-diketones.[a]



[a] Reaction conditions: α-diketone **1** (0.2 mmol), imine **3** (0.1 mmol), $P(OEt)_3$ (0.24 mmol), DPZ (0.1 mol%), DCE (1.0 mL), degassed with argon by three freeze–pump–thaw cycles, 3 W blue LED, 48 h, rt. [b] 0.3 mmol of **1** and 0.36 mmol of $P(OEt)_3$ used.

obtained in 98% yield. The substituents on the *N*-aryl ring can be varied, with product yields mostly ranging from good to excellent (**4a**–**4g**). *N*-Benzyl protection (**4q**) is another good option, giving β-lactam in very good yield too. The substitutions on the aryl rings of α-diketone **1**, electron-donating or -withdrawing, can also be largely tolerated, affording cycloaddition products smoothly (**4h**–**4n**). It is worth mentioning that two monocyclic β-lactam molecules with potent antibacterial and antifungal activities [15] (**4o**, **4p**) were synthesized in good yields by our concise strategy, comparing favorably with the originally reported method.[15] The Ar^1 group of the aldimine **3** could be tuned with different substitutions on the phenyl ring (**4r**–**4u**) or other aromatic systems (**4y**) to give the desired cycloadducts in up to 99% yields. Cyclic imines incorporated in fused ring systems (**4v**, **4w**) are also viable substrates for our strategy. In addition to aldimines, ketimines derived from aromatic ketones are also compatible substrates for the [2+2] cycloaddition, as exemplified by **4x**, thus greatly extending the imine scope of our method.

Mechanistic studies were carried out to gain insights into the reaction mechanism (Scheme 2). Firstly, control experiments showed that 1,3,2-dioxaphosphole **INT1** prepared in advance could be converted to diphenylacetate **2a** directly under the same conditions (Scheme 2a), suggesting that **INT1** might be the key intermediate to undergo the photoredox cycle. Then, when ethanol was applied as the solvent for the model Wolff rearrangement reaction, in addition to **2a**, two new products, that is, **5** and **6**, which could be generated through trapping α-keto carbene by HAT and H–O bond insertion reactions,[10] were obtained in 20% and 14% yield, respectively (Scheme 2b), serving as solid evidence for a stepwise Wolff rearrangement process. A cyclic voltammetry study showed that 1,3,2-dioxaphosphole **INT1** had a half-wave oxidation potential of +0.696 V (vs. SCE in CH_3CN, Scheme 2c, see Supporting Information for details), well below the reduction potential of excited state DPZ ($E^t(S^*/S^{\bullet-})$ = +1.42 V vs. SCE in CH_3CN).[14] Fluorescence quenching experiments (Scheme 2d) finally concluded that **INT1** was an active reductive quencher of the excited DPZ (*DPZ).



Scheme 2. Mechanistic studies.

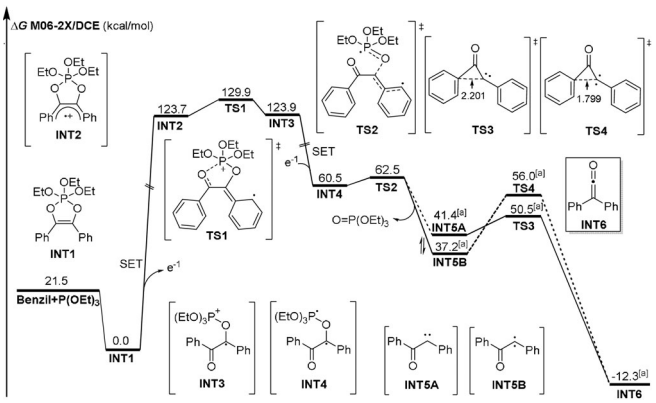


Figure 1. Free energy profiles of the photoredox Wolff rearrangement from benzil and triethyl phosphite. [a] Free energy with one mole of triethyl phosphate included.

To help further elucidate the detailed process of ketene generation, DFT computation at the M06-2X/def2-TZVPP/SMD(DCE)// B3LYP-D4/def2-TZVP level of theory[16] was conducted (Figure 1). As can be seen from the free energy profile of this transformation, the fission of the P–O bond in radical cation **INT2** is very fast, with an energy barrier of only 6.2 kcal mol^{-1}. Reduction of the radical cation **INT3** is highly exothermic (−63.4 kcal mol^{-1}), affording diradical **INT4**, which could undergo straightforward decomposition (energy barrier: 2.0 kcal mol^{-1}) to release the crucial α-keto carbene intermediate. Triplet carbene **INT5B**, only 4.2 kcal mol^{-1} more stable, is in fast equilibrium with the singlet state structure **INT5A**. However, Wolff rearrangement from **INT5B** to ketene **INT6** has a remarkably higher energy barrier than that from **INT5A** (18.8 vs. 9.1 kcal mol^{-1}), indicating that the rearrangement proceeds mainly from the singlet carbene intermediate at room temperature. This is consistent with the fact that halogenated solvents (such as DCE), which can selectively stablize singlet carbenes via halogen–carbene complexation,[17] greatly promote the Wolff rearrangement (Table 1, entry 6). The overall transformation from benzil and triethyl phosphite to ketene **INT6** is energetically favorable by −12.3 kcal mol^{-1}.

Based on mechanistic study results and our DFT computation study above, a photoredox catalytic Wolff rearrangement from α-diketones and phosphites is proposed herein (Figure 2). 1,3,2-Dioxaphosphole **INT1**, formed in situ at the initial stage, undergoes photoredox decomposition with the catalysis of the excited sensitizer DPZ*, to give α-keto carbene **INT5B**, which is in fast equilibrium with the singlet state **INT5A**. The Wolff rearrangement from the singlet state is the dominant process at room temperature, affording ketene **INT6** exothermically. Trapping the ketenes with alcohols yields diphenyl acetates **2**, while [2+2] cycloaddition with imines gives valuable β-lactams **4**. The intermediate carbene could also be trapped by alcohol via HAT or O–H bond insertion reaction to yield single-carbonyl reduced product **5** and α-alkoxy ketone **6**.

To demonstrate the application potential of this method, the Staudinger synthesis of β-lactams **4q** was scaled up to 1.0 mmol without noticeable decrease in yield, proving its

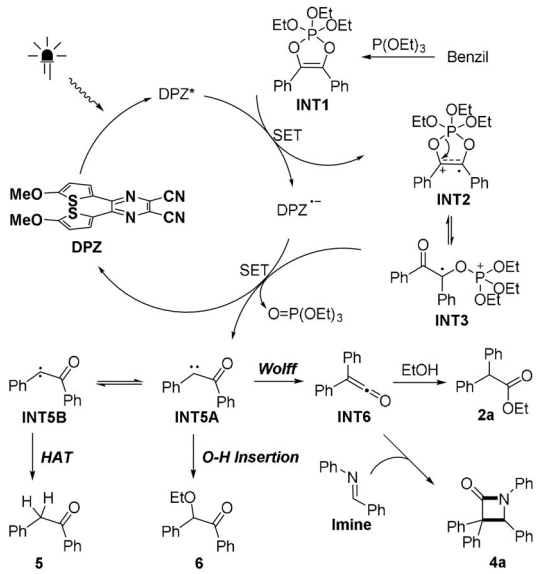
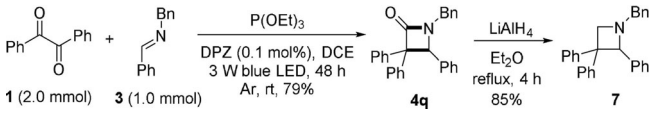


Figure 2. Proposed mechanism.



Scheme 3. Scale up and further transformation.

value in a practical synthetic context (Scheme 3). The lactam was reduced efficiently by lithium aluminium hydride in refluxing ether to give, in good yield, azetidine **7**, the core structure of many natural and non-natural bioactive molecules,[18] thus providing an attractive alternative strategy for its preparation.

In summary, by exploring the photoredox chemistry of 1,3,2-dioxaphospholes readily accessible from α-diketones and trialkyl phosphites, we developed a direct C=O bond deoxygenation strategy that provides novel access to the Wolff rearrangement which demands traditionally α-diazoketones as the precursors. The resulting ketenes can be trapped by nucleophilic alcohols/thiols to give α-aryl (thio)-acetates, or imines to afford, through [2+2] cycloaddition, valuable β-lactams which are the core structure of important antibiotic drugs and natural bioactive molecules. This strategy, notable for its high efficiency, environmental benignancy and operational simplicity, represents an unprecedented example of photoredox catalytic Wolff rearrangement from in situ formed 1,3,2-dioxaphospholes, and the first successful synthesis of β-lactams via photoredox Staudinger reaction from α-diketones. Furthermore, the reaction can be safely scaled up and the β-lactam core is able to be readily transformed to azetidine, underscoring the application potential of our strategy in not only the chemical preparation of β-lactam-containing bioactive molecules, but also other structurally related compounds.

Acknowledgements

Grants from the NSFC (21925103) and Henan Normal University are gratefully acknowledged.

Conflict of Interest

The authors declare no conflict of interest.

Keywords: photoredox catalysis · Staudinger reaction · Wolff rearrangement · α-diketones · β-lactams

[1] a) C. H. Zhou, J. N. Beltramini, Y. X. Fan, G. Q. Lu, *Chem. Soc. Rev.* **2008**, *37*, 527; b) J. J. Bozell, G. R. Petersen, *Green Chem.* **2010**, *12*, 539; c) P. N. R. Vennestrøm, C. M. Osmundsen, C. H. Christensen, E. Taarning, *Angew. Chem. Int. Ed.* **2011**, *50*, 10502; *Angew. Chem.* **2011**, *123*, 10686; d) A. M. Ruppert, K. Weinberg, R. Palkovits, *Angew. Chem. Int. Ed.* **2012**, *51*, 2564; *Angew. Chem.* **2012**, *124*, 2614; e) D. M. Alonso, S. G. Wettstein, J. A. Dumesic, *Chem. Soc. Rev.* **2012**, *41*, 8075; f) R. A. Sheldon, *Green Chem.* **2014**, *16*, 950.

[2] a) F. E. Chen, Z. R. Guo, *Method of Organic Pharmaceutical Synthesis*, Chinese Medicine Science and Technology Press, Beijing, **1998**, p. 56; b) M. V. Kumudhavalli, C. Margret, D. Sripriya, B. Jayakar, *Int. J. Pharm. Biol. Sci.* **2010**, *1*, 1.

[3] a) E. Furimsky, *Appl. Catal. A* **2000**, *199*, 147.

[4] a) E. Clemmensen, *Ber. Dtsch. Chem. Ges.* **1914**, *47*, 681; b) E. Vedejs, *Org. React.* **1975**, *22*, 401.

[5] L. Wolff, *Justus Liebigs Ann. Chem.* **1912**, *394*, 86.

[6] For selected reviews, see: a) M. C. Andrew, K. Prier, D. W. C. MacMillan, *Science* **2011**, *334*, 1114; b) C. K. Prier, D. A. Rankic, D. W. C. MacMillan, *Chem. Rev.* **2013**, *113*, 5322; c) D. M. Schultz, T. P. Yoon, *Science* **2014**, *343*, 1239176; d) J. W. Beatty, C. R. J. Stephenson, *Acc. Chem. Res.* **2015**, *48*, 1474; e) M. H. Shaw, J. Twilton, D. W. C. MacMillan, *J. Org. Chem.* **2016**, *81*, 6898; f) N. A. Romero, D. A. Nicewicz, *Chem. Rev.* **2016**, *116*, 10075; g) J. Twilton, C. C. Le, P. Zhang, M. H. Shaw, R. W. Evans, D. W. C. MacMillan, *Nat. Rev. Chem.* **2017**, *1*, 0052.

[7] a) R. Ruzi, J. Ma, X.-A. Yuan, W. Wang, S. Wang, M. Zhang, J. Dai, J. Xie, C. Zhu, *Chem. Eur. J.* **2019**, *25*, 12724; b) M. Zhang, X.-A. Yuan, C. Zhu, J. Xie, *Angew. Chem. Int. Ed.* **2019**, *58*, 312; *Angew. Chem.* **2019**, *131*, 318; c) M. Zhang, J. Xie, C. Zhu, *Nat. Commun.* **2018**, *9*, 3517; d) E. E. Stache, A. B. Ertel, T. Rovis, A. G. Doyle, *ACS Catal.* **2018**, *8*, 11134; e) P.-J. Xia, Z.-P. Ye, Y.-Z. Hu, D. Song, H.-Y. Xiang, X.-Q. Chen, H. Yang, *Org. Lett.* **2019**, *21*, 2658.

[8] a) K. Cao, S. M. Tan, R. Lee, S. Yang, H. Jia, X. Zhao, B. Qiao, Z. Jiang, *J. Am. Chem. Soc.* **2019**, *141*, 5437; b) B. Qiao, C. Li, X. Zhao, Y. Yin, Z. Jiang, *Chem. Commun.* **2019**, *55*, 7534; c) Y. Liu, X. Liu, J. Li, X. Zhao, B. Qiao, Z. Jiang, *Chem. Sci.* **2018**, *9*, 8094; d) L. Lin, X. Bai, X. Ye, X. Zhao, C.-H. Tan, Z. Jiang, *Angew. Chem. Int. Ed.* **2017**, *56*, 13842; *Angew. Chem.* **2017**, *129*, 14030.

[9] a) F. Ramirez, *Pure Appl. Chem.* **1964**, *9*, 337; b) W. C. Hamilton, S. J. La Placa, F. Ramirez, C. P. Smith, *J. Am. Chem. Soc.* **1967**, *89*, 2268; c) D. B. Denney, H. M. Relles, *J. Am. Chem. Soc.* **1964**, *86*, 3897; d) D. B. Denney, L. Saferstein, *J. Am. Chem. Soc.* **1966**, *88*, 1839; e) L. L. Chang, D. B. Denney, D. Z. Denney, R. J. Kazior, *J. Am. Chem. Soc.* **1977**, *99*, 2293; f) F. Ramirez, J. F. Marecek, *Tetrahedron* **1984**, *40*, 2837.

[10] For selected reviews on Wolff rearrangement, see: a) Y. Coquerel, J. Rodriguez, *The Wolff Rearrangement: Tactics, Strategies and Recent Applications in Organic Synthesis*, Wiley, Hoboken, **2015**; b) N. R. Candeias, A. F. Trindade, P. M. P. Gois, C. A. M. Afonso, *Comprehensive Organic Synthesis II*, Elsevier,

Amsterdam, **2014**, p. 944; c) W. Kirmse, *Eur. J. Org. Chem.* **2002**, 2193.
[11] For recent reviews on the chemical synthesis of β-lactams, see: a) C. R. Pitts, T. Lectka, *Chem. Rev.* **2014**, *114*, 7930; b) N. Fu, T. T. Tidwell, *Tetrahedron* **2008**, *64*, 10465; c) A. Brandi, S. Cicchi, F. M. Cordero, *Chem. Rev.* **2008**, *108*, 3988.
[12] H. Staudinger, *Justus Liebigs Ann. Chem.* **1907**, *356*, 51.
[13] a) L. Decuyper, M. Jukič, I. Sosič, A. Žula, M. D'hooghe, S. Gobec, *Med. Res. Rev.* **2018**, *38*, 426; b) P. Galletti, D. Giacomini, *Curr. Med. Chem.* **2011**, *18*, 4265.
[14] a) Y. Yin, Y. Li, T. P. Gonçalves, Q. Zhan, G. Wang, X. Zhao, B. Qiao, K.-W. Huang, Z. Jiang, *J. Am. Chem. Soc.* **2020**, *142*, 19451; b) H. Yang, G. Wei, Z. Jiang, *ACS Catal.* **2019**, *9*, 9599; c) T. Shao, Y. Li, N. Ma, C. Li, G. Chai, X. Zhao, B. Qiao, Z. Jiang, *iScience* **2019**, *16*, 410; d) X. Liu, Y. Liu, G. Chai, B. Qiao, X. Zhao, Z. Jiang, *Org. Lett.* **2018**, *20*, 6298; e) J. Li, M. Kong, B. Qiao, R. Lee, X. Zhao, Z. Jiang, *Nat. Commun.* **2018**, *9*, 2445; f) Y. Yin, Y. Dai, H. Jia, J. Li, L. Bu, B. Qiao, X. Zhao, Z. Jiang, *J. Am. Chem. Soc.* **2018**, *140*, 6083.
[15] G. S. Singh, E. Mbukwa, T. Pheko, *ARKIVOC* **2007**, 80.
[16] The M06 level of theory: a) Y. Zhao, D. G. Truhlar, *Theor. Chem. Acc.* **2008**, *120*, 215; The def2-TZVP and def2-TZVPP level of theory: b) F. Weigend, R. Ahlrichs, *Phys. Chem. Chem. Phys.* **2005**, *7*, 3297; The SMD level of theory: c) A. V. Marenich, C. J. Cramer, D. G. Truhlar, *J. Phys. Chem. B* **2009**, *113*, 6378; the B3LYP level of theory: d) P. J. Stephens, F. J. Devlin, C. F. Chabalowski, M. J. Frisch, *J. Phys. Chem.* **1994**, *98*, 11623; the atom-pairwise dispersion correction based on tight binding partial charges (D4): e) E. Caldeweyher, S. Ehlert, A. Hansen, H. Neugebauer, S. Spicher, C. Bannwarth, S. Grimme, *J. Chem. Phys.* **2019**, *150*, 154122; f) E. Caldeweyher, C. Bannwarth, S. Grimme, *J. Chem. Phys.* **2017**, *147*, 034112.
[17] J. Wang, J. Kubicki, H. Peng, M. S. Platz, *J. Am. Chem. Soc.* **2008**, *130*, 6604.
[18] a) J. P. Milton, J. S. Fossey, *Tetrahedron* **2021**, *77*, 131767; b) V. Mehra, I. Lumb, A. Anand, V. Kumar, *RSC Adv.* **2017**, *7*, 45763; c) D. Ferraris, S. Belyakov, W. Li, E. Oliver, Y.-S. Ko, D. Calvin, S. Lautar, B. Thomas, C. Rojas, *Curr. Top. Med. Chem.* **2007**, *7*, 597.

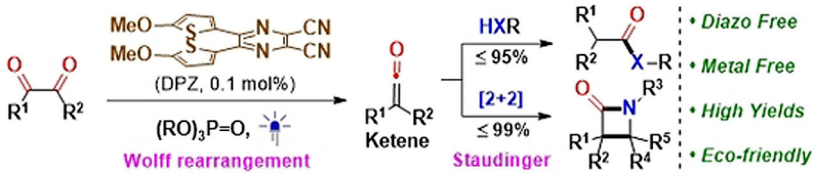
Manuscript received: May 27, 2021
Accepted manuscript online: June 17, 2021
Version of record online: ■■ ■■, ■■■■

Communications

Photoredox Catalysis

H. Yang, H. Li, G. Wei,*
Z. Jiang* ——— ■■■■–■■■■

Photoredox Catalytic Phosphite-Mediated Deoxygenation of α-Diketones Enables Wolff Rearrangement and Staudinger Synthesis of β-Lactams



Photocatalytic C=O bond activation is enabled by exploring the unprecedented photoredox chemistry of 1,3,2-dioxaphospholes formed from α-diketones and trialkyl phosphites, which provides a novel diazo-free access to the Wolff rearrangement. The strategy was successfully applied to the efficient synthesis of α-aryl (thio)acetates and valuable β-lactams.