A Journal of the Gesellschaft Deutscher Chemiker

Angewandte International Edition GDCh Chemie

www.angewandte.org

Accepted Article

Title: Synthesis of Hypervalent Iodine(III) Reagents Containing a Transferable (Diarylmethylene)amino Group and Their Use in the Oxidative Amination of Silyl Ketene Acetals

Authors: Kensuke Kiyokawa, Daichi Okumatsu, and Satoshi Minakata

To be cited as: *Angew. Chem. Int. Ed.* 10.1002/anie.201904971
Angew. Chem. 10.1002/ange.201904971

Link to VoR: http://dx.doi.org/10.1002/anie.201904971
http://dx.doi.org/10.1002/ange.201904971

WILEY-VCH

10.1002/anie.201904971

WILEY-VCH

Synthesis of Hypervalent Iodine(III) Reagents Containing a Transferable (Diarylmethylene)amino Group and Their Use in the Oxidative Amination of Silyl Ketene Acetals

Kensuke Kiyokawa,* Daichi Okumatsu, and Satoshi Minakata*

Abstract: The preparation of some hypervalent iodine reagents containing a transferable amino group derived from benzophenone imine derivatives are reported. The reagents could be readily prepared, stored as a bench-stable solid, and were successfully used in the transition-metal-free oxidative amination of silyl ketene acetals to afford the corresponding α-amino esters, whose benzophenone imine moieties could be easily hydrolyzed, leading to the formation of primary amines.

Oxidative amination is one of the most attractive transformations to access various types of nitrogen containing compounds, which are promising building blocks that can be used to prepare biologically active and medicinally important compounds. Hypervalent iodine reagents have emerged as a powerful tool in oxidative transformations,[1,2] and in the past decades, several examples of reagents containing transferable nitrogen functional groups such as imino (**I**),[3] bissulfonimido (**II**),[4,5] azido (**III**),[6] phthalimido (**IV**),[7,8] and sulfoximido (**V**)[9] groups have been developed for use in some unique oxidative amination reactions. However, despite recent advances, there continue to be problems associated with preparing amines utilizing those reagents. Indeed, although iminoiodane **I** and bisimidoiodane **II** are extensively used in the oxidative amination of unsaturated hydrocarbons and C–H bond amination,[3,4] it is frequently difficult to deprotect the amino group in the products, thus hampering the synthesis of primary amines and further elaboration of the amine products. Azidoiodane **III** has recently been recognized as a useful reagent for preparing organic azides in an oxidative manner.[6] Neverthless, it is well known that azides are hazardous substances and the fact that a laborious reduction process is needed is a disadvantage in amine synthesis. Synthetic application of **IV** in oxidative amination has remained limited even though a phthaloyl group can be easily removed to provide a primary amine.[7] Thus, the development of a new method that enables the introduction of a readily modifiable nitrogen-containing functional group into an organic molecule utilizing hypervalent iodine reagents continues to be a challenging task.[10]

Dr. K. Kiyokawa, D. Okumatsu, Prof. Dr. S. Minakata
Department of Applied Chemistry, Graduate School of Engineering, Osaka University, Yamadaoka 2-1, Suita, Osaka 565-0871 (Japan)
E-mail: kiyokawa@chem.eng.osaka-u.ac.jp
minakata@chem.eng.osaka-u.ac.jp

Supporting information for this article is given via a link at the end of the document.((Please delete this text if not appropriate))

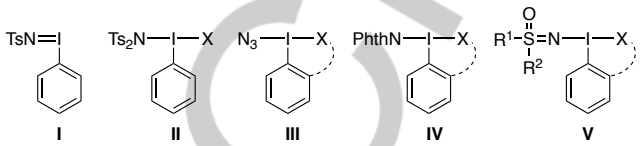
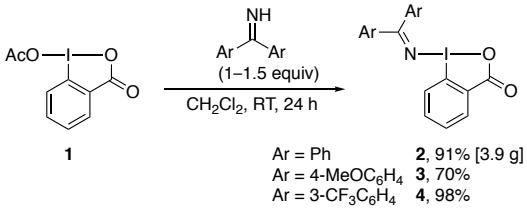


Figure 1. Representative examples of hypervalent iodine reagents that contain transferable nitrogen functional groups.

Benzophenone imine has been used as an aminating reagent in transition-metal catalyzed amination[11] and catalytic C–H amination,[12] and the resulting aminated products can be easily hydrolyzed to give primary amines. In addition, *N*-stannyl benzophenone imine has been applied to a radical alkylation reaction.[13] Meanwhile, benzophenone imine-derived oxime derivatives function as an electrophilic aminating reagent, which enables the amination of alkynyl copper reagents,[14a] Grignard reagents,[14b] and organoboron compounds with a copper catalyst.[14c] In this context, we hypothesized that hypervalent iodine reagents combined with benzophenone imine would offer a promising tool for oxidative amination to deliver modifiable amine products. Herein, we report on the development of some hypervalent iodine reagents that contain a benzophenone imine-derived nitrogen functional group and their use in the oxidative amination of silyl ketene acetals to provide α-amino acid derivatives.

Our initial efforts focused on the synthesis of the hypervalent iodine reagent **2** having a benziodoxolone skeleton along with the stability of the product (Scheme 1).[15] Gratifyingly, the synthesis of the desired **2** was achieved by a simple ligand exchange process. Indeed, acetoxyiodane **1** reacted smoothly with benzophenone imine in dichloromethane at room temperature to furnish the desired **2** in high yield, even in the case of a gram-scale synthesis (3.9 g, 91%). This simple process was successfully applied to the synthesis of derivatives containing electron-donating methoxy (**3**) and electron-withdrawing trifluoromethyl (**4**) groups. The synthesized reagents were reasonably stable under ambient conditions in the solid state as well as in solution. Single crystals of a representative sample of **2** suitable for X-ray crystallographic analysis were grown by the slow diffusion of an acetonitrile solution.[16,17] Structural data for **2** revealed that the benzophenone imine moiety was N-bound to the hypervalent iodine(III) center, which shows a typical distorted T-shaped geometry (Figure 2). The length of the I–N bond of 2.083(3) Å is somewhat longer than that observed for the sulfoximidoyl-containing hypervalent iodine reagent reported by Bolm and co-workers.[9a] In the solid state, **2** exists as a monomer with no intermolecular secondary bonding interactions around the iodine center, which is consistent with the fact that it is soluble in organic solvents, such as chloroform and dichloromethane.



Scheme 1. Syntheses of hypervalent iodine reagents containing a benzophenone imine-derived nitrogen functional group.

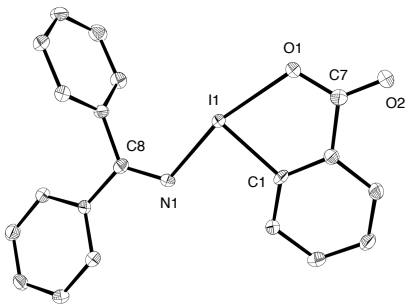
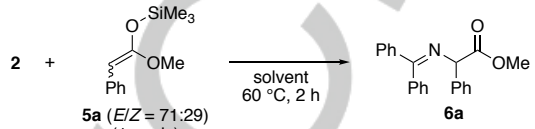


Figure 2. Crystal structure of **2** (hydrogen atoms are omitted for clarity). Thermal ellipsoids are shown at the 50% probability level. Selected bond lengths [Å] and angles [°]: I1–N1 2.083(3), I1–O1 2.312(3), I1–C1 2.114(4), N1–C8 1.291(5), O1–I1–N1 165.16(10); N1–I1–C1 88.90(13), O1–I1–C1 76.56(12), I1–O1–C7 114.7(2), I1–N1–C8 115.7(2).

We next turned our attention to exploring the reactivity of the synthesized hypervalent iodine reagents. The direct oxidative α-amination of carbonyl compounds in the carboxylic acid oxidation state is one of the most straightforward methods for preparing unnatural α-amino acid derivatives,[18] which are promising structural motifs for the preparation of biologically active molecules. In addition to direct methods, the oxidative amination of silyl ketene acetals is also a practical and reliable strategy, and several transition metal-catalyzed approaches have been reported to date, in which iminoiodanes,[19a,b] hydroxyamines,[19c] and chloramines[19d] were used as a nitrogen source. However, a remaining issue is the need for transition-metal catalysts to be used and difficulties associated with the further elaboration of an amino group in the products. In this context, we were pleased to find that the hypervalent iodine reagent **2** was capable of aminating silyl ketene acetals without the addition of any catalyst or additive.

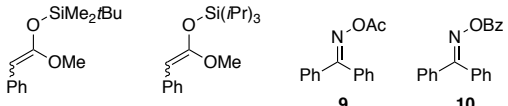
When the silyl ketene acetal **5a** (*E*/*Z* = 71:29) derived from methyl phenylacetate was employed in the reaction with **2** in 1,2-dichloroethane at 60 °C, oxidative amination occurred to give the desired **6a** in 42% yield (Table 1, Entry 1). The results of a solvent screening revealed that the yield of **6a** could be increased to 70% when MeCN was used (Entry 2). Reactions in other polar solvents, such as DMF, THF, and $MeNO_2$, resulted in lower yields of **6a** than that in MeCN (Entries 3–5) while no desired product was formed when HFIP and toluene were used as the solvent (Entries 6 and 7). Increasing the amounts of reagents used were effective, and the use of 1.5 equivalents of **5a** gave the best result (Entries 8 and 9). The *E*/*Z* configuration of a silyl ketene acetal would little affect the efficiency of the reaction because (*Z*)-**5a** (*E*/*Z* = 9:91) provided the same yield (Entry 2 vs. 10). Silyl ketene acetals bearing a bulky silyl group, such as *tert*-butyldimethylsilyl (**7**) and triisopropylsilyl (**8**) groups, were also applicable to this amination but their reactivity was lower than that of **5a** (Entries 11 and 12). No reaction was observed with benzophenone imine-derived oxime derivatives that can function as electrophilic aminating reagents (Entries 13 and 14).[14] Conducting the reaction at room temperature resulted in a lower yield of **5a** (Entry 15). The reaction proceeded with comparable efficiency, even in the dark, demonstrating that the reaction is a thermal process (Entry 16).

Table 1. Effect of solvents and reaction parameters on the oxidative amination of the silyl ketene acetal **5a** and control experiments.[a]



Entry	Solvent	Yield [%][b]
1	1,2-Dichloroethane	42
2	MeCN	70
3	DMF	45
4	THF	39
5	$MeNO_2$	12
6	HFIP	0
7	Toluene	0
Entry	**Deviation from the conditions of Entry 2**	**Yield [%][b]**
8	**2** (1.5 equiv)	74
9	**5a** (1.5 equiv)	82
10	(*Z*)-**5a** (*E*/*Z* = 9:91) instead of **5a** (*E*/*Z* = 71:29)	70
11	**7** instead of **5a**, 12 h	58
12	**8** instead of **5a**, 12 h	52
13	**9** instead of **2**, 12 h	0
14	**10** instead of **2**, 12 h	0
15	RT	48
16	In the dark	66

[a] Reactions were performed on a 0.2 mmol scale. [b] Determined by ^{1}H NMR analysis of the crude product using 1,1,2,2-tetrachloroethane as an internal standard.

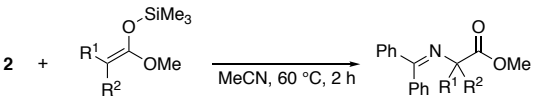


With the optimized reaction conditions in hand (Table 1, Entry 9), the substrate scope of the amination was investigated (Table 2). A series of silyl ketene acetals containing electron-rich and -deficient aryl groups at the 2-position were subjected to amination with **2**, and all of the reactions proceeded successfully to afford the corresponding α-amino esters in good to high yields (Entries 1–6). The presence of a methyl substituent on the *o*- or *m*-positions did not affect the reactivity (Entries 7 and 8). An electron-rich *N*-methyl indolyl group was well tolerated under the oxidative conditions to provide the desired **6i** (Entry 9). In addition, silyl ketene acetals containing aliphatic substituents at the 2-position were also suitable for this amination. For example, substrates containing *n*-butyl (**5j**) and sterically hindered

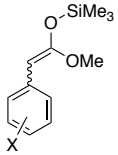
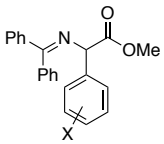
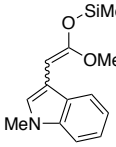
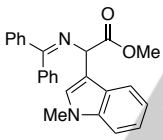
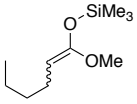
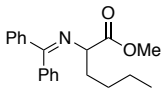
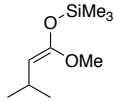
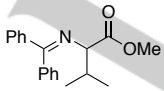
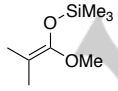
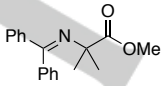
10.1002/anie.201904971

isopropyl (**5k**) groups were smoothly converted into the corresponding α-amino esters (Entries 10 and 11). Furthermore, the sterically demanding dimethyl-substituted **5l** was also transformed into **6l** containing an α-tertiary amine moiety in moderate yield (Entry 12). However, unfortunately, the present method could not be applied to the amination of a silyl enol ether derived from acetophenone (not shown).

Table 2. Substrate scope.[a]

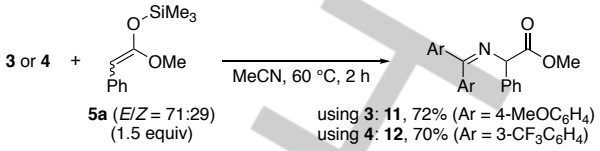


5 (1.25–2 equiv) **6**

Entry	5	6	Yield [%]
			
1	**5a**, X = H (*E*/*Z* = 71:29)	**6a**	78
2	**5b**, X = 4-OMe (*E*/*Z* = 93:7)	**6b**	73
3	**5c**, X = 4-Me (*E*/*Z* = 74:26)	**6c**	73
4	**5d**, X = 4-Cl (*E*/*Z* = 64:36)	**6d**	83
5	**5e**, X = 4-Br (*E*/*Z* = 63:37)	**6e**	76
6	**5f**, X = 4-CF_3 (*E*/*Z* = 40:60)	**6f**	84
7	**5g**, X = 2-Me (*E*/*Z* = 60:40)	**6g**	75
8	**5h**, X = 3-Me (*E*/*Z* = 74:26)	**6h**	75
9[b]	 **5i**[c]	 **6i**	55
10	 **5j**[c]	 **6j**	51
11	 **5k** (*E*/*Z* = >95:5)	 **6k**	63
12	 **5l**	 **6l**	58

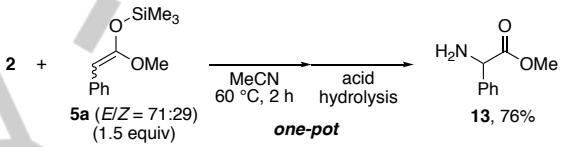
[a] Reactions were performed on a 0.4 mmol scale. Yields are isolated yields. The isolated products contained a small amount of dimers of **5**. See the Supporting Information for details. [b] Reaction was conducted at RT. [c] *E*/*Z* ratios were not determined.

Oxidative amination was also examined using derivatives **3** and **4** that contain electron-rich and -deficient imine moieties, respectively (Scheme 2). Both reagents could be used to deliver the corresponding products in yields comparable to those for the reaction using **2**, indicating that the amination was not significantly influenced by the electronic property of the imine moiety of the hypervalent iodine reagent.



Scheme 2. Oxidative amination using hypervalent iodine reagents **3** and **4**.

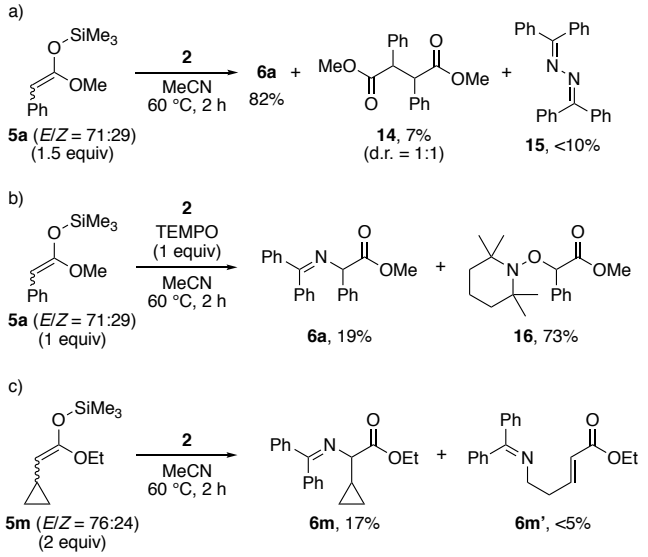
It is well known that a benzophenone imine moiety is be easily hydrolyzed, and this allowed us to carry out a one-pot synthesis of the unprotected α-amino ester **13** (Scheme 3). A sequential one-pot protocol consisting of the oxidative amination of **5a** with **2**, removal of the volatiles under reduced pressure, and acid hydrolysis at room temperature followed by a simple basic workup, afforded desired **13** in good yield. This quite simple method offers a useful and practical process for the synthesis of α-amino acid derivatives.



Scheme 3. Synthesis of a primary amine via a one-pot procedure.

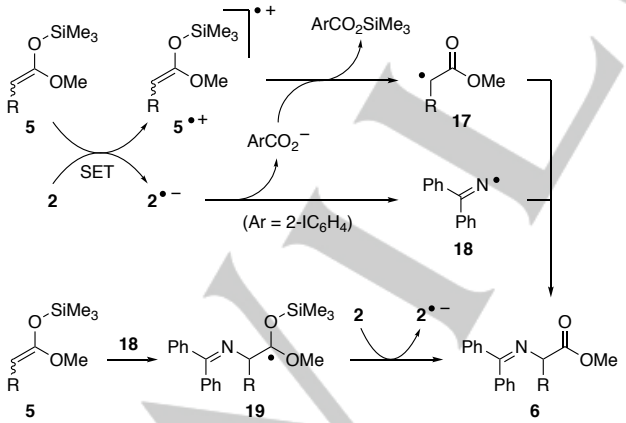
Mechanistic aspects of the oxidative amination were also investigated. Both ^{1}H NMR and GC-MS analysis of byproducts in the amination of **5a** (Table 1, Entry 9) revealed that a small amount of **14** and benzophenone azine (**15**) were generated, which were likely formed through the homocoupling of the corresponding α-carbonyl radicals and iminyl radicals, respectively (Scheme 4a).[20,21] To examine this issue further, we carried out a radical trapping experiment using 2,2,6,6-tetramethyl-piperidin-1-oxyl (TEMPO). When TEMPO was added to the amination reaction of **5a**, the formation of **6a** was suppressed (19%), and **16** was produced as the main product through the trapping of an α-carbonyl radical derived from **5a** by TEMPO (Scheme 4b).[22] These results clearly indicate that an α-carbonyl radical **17** as well as an iminyl radical **18** (in Scheme 5) are generated in situ and both participate in the amination step. A radical mechanism was further confirmed by a radical clock experiment using the silyl ketene acetal **5m** containing a cyclopropyl substituent (Scheme 4c).[23] When **5m** was subjected to the amination reaction conditions, the cyclopropane-contining **6m** was formed in low yield, and some ring-opening products (not fully characterized) were observed, one of which was determined to be **6m'**.[24]

10.1002/anie.201904971



Scheme 4. Mechanistic investigations into the oxidaitve amination reaction. a) Byproducts in the standard amination reaction. b) Radical trapping experiment with TEMPO. c) Reaction of cyclopropane-containing **5m**. Yields are determined by ^{1}H NMR analysis of the crude product.

Based on these experimental results, a proposed reaction pathway is depicted in Scheme 5. The reaction is initiated through a single electron transfer (SET) from the silyl ketene acetal **5** to the hypervalent iodine reagent **2**.[25,26] The resulting radical cation and anion species are then quickly decomposed to form the α-carbonyl radical **17** and the iminyl radical **18**, respectively, which are then rapidly coupled to produce the α-amino ester **6**. In addition, given the fact that the formation of a certain amount of **6a**, even in the presence of TEMPO (Scheme 4b) and that the cyclopropane-containing product **6m** is formed (Scheme 4c), an alternative pathway including a radical addition of **18** to **5** followed by single-electron oxidation of the resulting **19** by **2**, is also a possible pathway.[25,27,28]



Scheme 5. Proposed reaction pathway.

In conclusion, benziodoxolone-based hypervalent iodine reagents containing a transferable (diarylmethylene)amino group were prepared and found to be reasonably stable under ambient conditions. A representative compound was structurally characterized by X-ray analysis. In addition, using these reagents, the transition-metal-free oxidative amination of silyl ketene acetals was developed to afford α-amino acid derivatives. These preliminary studies demonstrate that these new types of hypervalent iodine reagents can function as useful aminating reagents for the synthesis of primary amines. Further investigations focused on expanding the utility of iodine reagents such as these for organic synthesis are currently in progress.

Acknowledgements

This work was supported by JSPS KAKENHI Grant Numbers 19H02716 (S.M.) and 18K14217 (K.K.). We thank Dr. Norimitsu Tohnai (Osaka University) for assistance with X-ray crystallographic analysis.

Keywords: amination • amino acids • iodine • radical • synthetic methods

[1] a) V. V. Zhdankin, *Hypervalent Iodine Chemistry: Preparation, Structure and Synthetic Application of Polyvalent Iodine Compounds*, Wiley, New York, **2014**; b) *Hypervalent Iodine Chemistry*, (Ed.: T. Wirth), in: *Topics in Current Chemistry*, Vol. 373, Springer, Berlin, **2016**.

[2] For selected reviews on chemistry of hypervalent iodine compounds, see: a) T. Wirth, *Angew. Chem. Int. Ed.* **2005**, *44*, 3656–3665; *Angew. Chem.* **2005**, *117*, 3722–3731; b) V. V. Zhdankin, P. J. Stang, *Chem. Rev.* **2008**, *108*, 5299–5358; c) E. A. Merritt, B. Olofsson, *Angew. Chem. Int. Ed.* **2009**, *48*, 9052–9070; *Angew. Chem.* **2009**, *121*, 9214–9234; d) M. Uyanik, K. Ishihara, *ChemCatChem* **2012**, *4*, 177–185; e) R. Samanta, K. Matcha, A. P. Antonchick, *Eur. J. Org. Chem.* **2013**, 5769–5804; f) F. V. Singh, T. Wirth, *Chem. Asian J.* **2014**, *9*, 950–971; g) A. Yoshimura, V. V. Zhdankin, *Chem. Rev.* **2016**, *116*, 3328–3435; h) Y. Li, D. P. Hari, M. V. Vita, J. Waser, *Angew. Chem. Int. Ed.* **2016**, *55*, 4436–4454; *Angew. Chem.* **2016**, *128*, 4512–4531.

[3] a) S. Minakata, Y. Takeda, K. Kiyokawa in *Methods and Applications of Cycloaddition Reactions in Organic Syntheses* (Eds.: N. Nishiwaki), Wiley-VCH, Weinheim, **2013**, chap. 2. For selected reviews, see: b) P. Müller, C. Fruit, *Chem. Rev.* **2003**, *103*, 2905–2920; c) J. W. W. Chang, T. M. U. Ton, P. W. H. Chan, *Chem. Rec.* **2011**, *11*, 331–357. For selected examples, see: d) D. Macikenas, E. Skrzypczak-Jankun, J. D. Protasiewicz, *J. Am. Chem. Soc.* **1999**, *121*, 7164–7165; e) A. Yoshimura, V. N. Nemykin, V. V. Zhdankin, *Chem. Eur. J.* **2011**, *17*, 10538–10541; f) Y. Kobayashi, S. Masakado, Y. Takemoto, *Angew. Chem. Int. Ed.* **2018**, *57*, 693–697; *Angew. Chem.* **2018**, *130*, 701–705.

[4] a) C. Röben, J. A. Souto, Y. González, A. Lishchynskyi, K. Muñiz, *Angew. Chem. Int. Ed.* **2011**, *50*, 9478–9482; *Angew. Chem.* **2011**, *123*, 9650–9654; b) J. A. Souto, D. Zian, K. Muñiz, *J. Am. Chem. Soc.* **2012**, *134*, 7242–7245; c) J. A. Souto, P. Becker, A. Iglesias, K. Muñiz, *J. Am. Chem. Soc.* **2012**, *134*, 15505–15511; d) J. A. Souto, C. Martínez, I. Velilla, K. Muñiz, *Angew. Chem. Int. Ed.* **2013**, *52*, 1324–1328; *Angew. Chem.* **2013**, *125*, 1363–1367; e) C. Röben, J. A. Souto, E. C. Escudero-Adán, K. Muñiz, *Org. Lett.* **2013**, *15*, 1008–1011; f) K. Muñiz, *Acc. Chem. Res.* **2018**, *51*, 1507–1519.

[5] a) K. Moriyama, K. Ishida, H. Togo, *Org. Lett.* **2012**, *14*, 946–949; b) K. Ishida, H. Togo, K. Moriyama, *Chem. Asian J.* **2016**, *11*, 3583–3588.

[6] a) V. V. Zhdankin, C. J. Kuehl, A. P. Krasutsky, M. S. Formaneck, J. T. Bolz, *Tetrahedron Lett.* **1994**, *35*, 9677–9680; b) S. Akai, T. Okuno, M. Egi, T. Takada, H. Tohma, Y. Kita, *Heterocycles* **1996**, *42*, 47–51; c) V. V. Zhdankin, A. P. Krasutsky, C. J. Kuehl, A. J. Simonsen, J. K. Woodward, B. Mismash, J. T. Bolz, *J. Am. Chem. Soc.* **1996**, *118*, 5192–5197; d) S. Alazet, J. Preindl, R. Simonet-Davin, S. Nicolai, A. Nanchen, T. Meyer, J. Waser, *J. Org. Chem.* **2018**, *83*, 12334–12356 and references therein.

[7] a) M. Papadopoulou, A. Varvoglis, *J. Chem. Res.* **1983**, 66–67; b) L. Hadjiarapoglou, S. Spyroudis, A. Varvoglis, *Synthesis* **1983**, 207–208; c) K. Kiyokawa, S. Yahata, T. Kojima, S. Minakata, *Org. Lett.* **2014**, *16*, 4646–4649; d) L. Marchetti, A. Kantak, R. Davis, B. DeBoef, *Org. Lett.* **2015**, *17*, 358–361; e) A. A. Kantak, L. Marchetti, B. DeBoef, *Chem. Commun.* **2015**, *51*, 3574–3577; f) K. Kiyokawa, T. Kosaka, T. Kojima,

S. Minakata, *Angew. Chem. Int. Ed*. **2015**, *54*, 13719–13723; *Angew. Chem.* **2015**, *127*, 13923–13927; g) J. Bergès, B. García, K Muñiz, *Angew. Chem. Int. Ed.* **2018**, *57*, 15891–15895; *Angew. Chem.* **2018**, *130*, 16118–16112.

[8] For saccharin-based Imidoiodanes, see: a) M. Papadopoulou, A. Varvoglis, *J. Chem. Res.* **1984**, 166–167; b) A. Yoshimura, S. R. Koski, J. M. Fuchs, A. Saito, V. N. Nemykin, V. V. Zhdankin, *Chem. Eur. J.* **2015**, *21*, 5328–5331.

[9] a) H. Wang, Y. Cheng, P. Becker, G. Raabe, C. Bolm, *Angew. Chem. Int. Ed.* **2016**, *55*, 12655–12658; *Angew. Chem.* **2016**, *128*, 12845–12848; b) H. Wang, D. Zhang, H. Sheng, C. Bolm, *J. Org. Chem.* **2017**, *82*, 11854–11858; c) H. Wang, D. Zhang, C. Bolm, *Angew. Chem. Int. Ed.* **2018**, *57*, 5863–5866; *Angew. Chem.* **2018**, *130*, 5965–5968; d) H. Wang, D. Zhang, C. Bolm, *Chem. Eur. J.* **2018**, *24*, 14942–14945; e) H. Wang, D. Zhang, M. Cao, C. Bolm, *Synthesis* **2019**, *51*, 271–275.

[10] For examples of oxidative aminations of phenols, see: a) N. A. Braun, M. A. Ciufolini, K. Peters, E.-M. Peters, *Tetrahedron Lett.* **1998**, *39*, 4667–4670 ; b) N. A. Braun, J. D. Bray, M. A. Ciufolini, *Tetrahedron Lett.* **1999**, *40*, 4985–4988; c) N. A. Braun, M. Ousmer, J. D. Bray, D. Bouchu, K. Peters, E.- M. Peters, M. A. Ciufolini, *J. Org. Chem.* **2000**, *65*, 4397–4408; d) G. Scheffler, H. Seike, E. J. Sorensen, *Angew. Chem. Int. Ed.* **2000**, *39*, 4593–4596; *Angew. Chem*. **2000**, *112*, 4783–4785

[11] a) J. P. Wolfe, J. Åhman, J. P. Sadighi, R. A. Singer, S. L. Buchwald, *Tetrahedron Lett.* **1997**, *38*, 6367–6370; b) G. Mann, J. F. Hartwig, M. S. Driver, C. Fernández-Rivas, *J. Am. Chem. Soc.* **1998**, *120*, 827–828; c) D. M. Peacock, C. B. Roos, J. F. Hartwig, *ACS Cent. Sci.* **2016**, *2*, 647–652; d) R. Mao, J. Balon, X. Hu, *Angew. Chem. Int. Ed.* **2018**, *57*, 9501–9504; *Angew. Chem.* **2018**, *130*, 9645–9648.

[12] a) A. Laouiti, M. M. Rammah, M. B. Rammah, J. Marrot, F. Couty, G. Evano, *Org. Lett.* **2012**, *14*, 6–9; b) H. Huang, W. Chen, Y. Xu, J. Li, *Green Chem.* **2015**, *17*, 4715–4719; c) S. Kramer, *Org. Lett.* **2019**, *21*, 65–69.

[13] M.-C. Lamas, S. E. Vaillard, B. Wibbeling, A. Studer, *Org. Lett.* **2010**, *12*, 2072–2075.

[14] a) E.-U. Würthwein, R. Weigmann, *Angew. Chem. Int. Ed.* **1987**, *26*, 923–924; *Angew. Chem.* **1987**, *99*, 918–919; b) H. Tsutsumi, T. Ichikawa, K. Narasaka, *Bull. Chem. Soc. Jpn.* **1999**, *72*, 1869–1878; c) S. Liu, Y. Yu, L. S. Liebeskind, *Org. Lett*. **2007**, *9*, 1947–1950.

[15] a) G. Zheng, X. Ma, J. Li, D. Zhu, M. Wang, *J. Org. Chem.* **2015**, *80*, 8910–8915; b) Z. Zhao, Z. P. Yongli, H. Liu, C. Li, J. Zhao, *J. Org. Chem.* **2017**, *82*, 11848–11853.

[16] CCDC 1906200 contains the supplementary crystallographic data for this paper.

[17] Although crystallographic data for **2** was posted on the Cambridge Structure Database (CSD) by Chen and co-workers, as far as we know, neither methods for the synthesis of **2** nor its synthetic applications have been reported. H. Huang, M. Liu, Y. Chen, CCDC 1487384: Experimental Crystal Structure Determination, **2016**, DOI: 10.5517/ccdc.csd.cc1lxr4d

[18] For selected examples of α-amination of carbonyl compounds in the carboxylic acid oxidation state, see: a) D. A. Evans, S. G. Nelson, *J. Am. Chem. Soc.* **1997**, *119*, 6452–6453; b) J. A. Smulik, E. Vedejs, *Org. Lett.* **2003**, *5*, 4187–4190; c) B. Zhao, H. Du, Y. Shi, *J. Am. Chem. Soc.* **2008**, *130*, 7220–7221; d) R. W. Evans, J. R. Zbieg, S. Zhu, W. Li, D. W. C. MacMillan, *J. Am. Chem. Soc.* **2013**, *135*, 16074–16077; e) D. J. Fisher, G. L. Burnett, R. Velasco, J. Read de Alaniz, *J. Am. Chem. Soc.* **2015**, *137*, 11614–11617; f) K. Tokumasu, R. Yazaki, T. Ohshima, *J. Am. Chem. Soc.* **2016**, *138*, 2664–2669; g) V. Tona, A. de la Torre, M. Padmanaban, S. Ruider, L. González, N. Maulide, *J. Am. Chem. Soc.* **2016**, *138*, 8348–8351; h) M. Shang, X. Wang, S. M. Koo, J. Youn, J. Z. Chan, W. Yao, B. T. Hastings, M. Wasa, *J. Am. Chem. Soc.* **2017**, *139*, 95–98.

[19] a) D. A. Evans, M. M. Faul, M. T. Bilodeau, *J. Am. Chem. Soc.* **1994**, *116*, 2742–2753; b) M. Tanaka, Y. Kurosaki, T. Washio, M. Anada, S. Hashimoto, *Tetrahedron Lett.* **2007**, *48*, 8799–8802; c) N. Matsuda, K. Hirano, T. Satoh, M. Miura, *Angew. Chem. Int. Ed.* **2012**, *51*, 11827–11831; *Angew. Chem.* **2012**, *124*, 11997–12001; d) T. Miura, M. Morimoto, M. Murakami, *Org. Lett.* **2012**, *14*, 5214–5217.

[20] M. W. Rathke, A. Lindert, *J. Am. Chem. Soc.* **1971**, *93*, 4605–4606.

[21] A. R. Forrester, M. Gill, J. S. Sadd, R. H. Thomson, *J. Chem. Soc., Chem. Commun.* **1975**, 291–292.

[22] Control experiments confirmed that no reaction was observed in the absence of either **5a** or **2**, indicating that TEMPO did not directly react with either of them.

[23] A. L. J. Beckwith, V. W. Bowry, *J. Am. Chem. Soc.* **1994**, *116*, 2710–2716.

[24] See the Supporting Information for details.

[25] D. Katayev, V. Matoušek, R. Koller, A. Togni, *Org. Lett.* **2015**, *17*, 5898–5901.

[26] Cyclic voltammetry (CV) of **2** in CH_2Cl_2 exhibited an irreversible reduction wave at E_{pc} = −1.92 V vs Fc/Fc^+. See the Supporting Information for details.

[27] For examples of radical amination of silyl enol ethers, see: a) M. Zlotorzynska, H. Zhai, G. M. Sammis, *J. Org. Chem.* **2010**, *75*, 864–872; b) H. Zhai, J. G. Wickenden, G. M. Sammis, *Synlett* **2010**, 3035–3038.

[28] For selected reviews on chemistry of nitrogen-centered radicals, see: a) L. Stella in *Radicals in Organic Synthesis*, *Vol. 2* Eds.: P. Renaud, M. P. Sibi, Wiley-VCH, Weinheim, **2001**, pp. 407–426; b) S. Z. Zard, *Chem. Soc. Rev*. **2008**, *37*, 1603–1618; c) M. Minozzi, D. Nanni, P. Spagnolo, *Chem. Eur. J.* **2009**, *15*, 7830–7840; d) J.-R. Chen, X.-Q. Hu, L.-Q. Lu, W.-J. Xiao, *Chem. Soc. Rev.* **2016**, *45*, 2044–2056; e) T. Xiong, Q. Zhang, *Chem. Soc. Rev*. **2016**, *45*, 3069–3087; f) M. D. Kärkäs, *ACS Catal.* **2017**, *7*, 4999–5022.

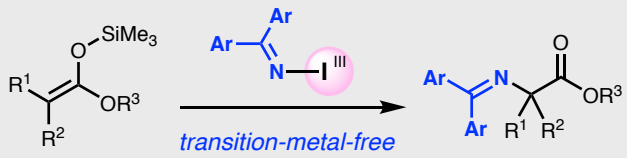
10.1002/anie.201904971

WILEY-VCH

Entry for the Table of Contents (Please choose one layout)

Layout 2:

COMMUNICATION



The preparation of some hypervalent iodine reagents containing a transferable amino group derived from benzophenone imine derivatives are reported. The reagents could be readily prepared, stored as a bench-stable solid, and were successfully used in the transition-metal-free oxidative amination of silyl ketene acetals to afford the corresponding α-amino esters, whose benzophenone imine moieties could be easily hydrolyzed, leading to the formation of primary amines.

Kensuke Kiyokawa, Daichi Okumatsu, and Satoshi Minakata**

Page No. – Page No.

Synthesis of Hypervalent Iodine(III) Reagents Containing a Transferable (Diarylmethylene)amino Group and Their Use in the Oxidative Amination of Silyl Ketene Acetals