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Zwitterion-Catalyzed Intermolecular Bromoesterifications

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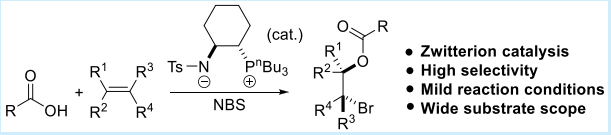
ABSTRACT: Intermolecular haloesterification is an important class of transformations. The resulting products are valuable building blocks. However, it is often necessary to use super-stoichiometric amount of acid in order to compensate the low reactivity. Herein, we report a zwitterion-catalyzed intermolecular bromoesterification using acid and olefin in an equimolar ratio. Mechanistic study revealed that the charge pair in the zwitterion works synergistically in activating both NBS and carboxylic acid.



Electrophilic halofunctionalization of olefins is an important class of organic transformations in which two functionalities can be introduced across C−C bonds in a vicinal relationship. The residual halogen handles can readily be converted into other functionalities using conventional methods. Haloesterification is one of the most studied reactions in electrophilic halogenation because the resultant products are valuable in various aspects.[1] Both intra- and intermolecular versions have been studied extensively. Intramolecular haloesterification (i.e., halolactonization) of olefinic acids to give lactones is comparably more efficient than that of the intermolecular version in most cases. It is believed that the nucleophilic carboxylate groups could interact with olefins reversibly and increase the reactivity of olefins toward electrophilic halogenations by increasing the olefin's HOMO energy.[2] Thus, tethering the olefins and carboxylic acids would preorganize them, and the halolactonization would be facilitated because of the decreased entropy.[3]

Compared to halolactonization, intermolecular haloesterification of olefins, which involves the use of three molecular entities (electrophilic halogen source, olefin, and carboxylic acid), is generally less efficient. Various strategies have been used to enhance the reaction efficiency. Neutral organocatalysts have been widely utilized to catalyze intermolecular haloesterification reactions. Examples with catalysts such as 1,4-diazabicyclo[2.2.2]octane (DABCO),[4] isoselenazolones,[5] tetramethylguanidine,[6] amidines,[7] $DHQD_2(PHAL)$,[8] phosphoric acid,[9] and indole[10] are documented. Another strategy involves the use of highly electrophilic brominating agents such as *N*,*N*-dibromo-*p*-toluenesulfonamide ($TsNBr_2$),[11] tribromoisocyanuric acid,[12] and bromide/bromate mixture.[13] The use of electrochemical oxidation in this type of transformation was also reported.[14] Very recently, the challenging catalytic asymmetric iodoesterification of olefins was accomplished using binuclear zinc complexes as the chiral catalysts.[15] In many circumstances, however, superstoichiometric amount (e.g., >2 equiv or as a cosolvent) of carboxylic acids is still needed to compensate the low reaction efficiency. Thus, a catalytic system that enables an effective preorganization of reaction partners and avoids the use of excessive substrates remains highly desirable.

Zwitterions are an emerging class of organocatalysts.[16,17] Unlike many bifunctional organocatalysts that are often constructed based on neutral functional components such as Brønsted bases/acids, Lewis bases, or dihydrogen bonds,[18] zwitterions consist of separated positive and negative formal charges, while the molecules are overall neutral.[19] However, catalysis using zwitterion remains underexplored. Very recently, our group has successfully developed the amide/iminium zwitterionic catalysts for transesterification and dehydrative esterification.[20] We speculated that the bifunctional zwitterionic catalysts could be applied to the intermolecular bromoesterification of olefins, where both bromine sources and carboxylic acids could be activated within the catalyst scaffolds. Herein, we report the application of novel bifunctional amide/phosphonium type zwitterions in catalyzing intermolecular bromoesterification using equimolar of olefins and carboxylic acids with *N*-bromosuccinimide (NBS) as the brominating agent.

At the outset of the investigation, intermolecular bromoesterification of styrene (**2a**) was studied using equimolar amounts of benzoic acid (**1a**) as the nucleophilic carboxylate source and NBS as the electrophilic bromine source (Table 1). In the absence of catalyst, no product was detected after 20 h (entry 1). To our delight, zwitterionic catalysts (±)-**4a** and (±)-**4b** derived from 4-dimethylaminopyridine (DMAP) and 4-pyrrolidinopyridine[20] gave moderate catalytic performance (entries 2 and 3). Replacement of the pyridinium moiety in (±)-**4a** by phosphonium (i.e., zwitterion (±)-**4c**)[21] gave the

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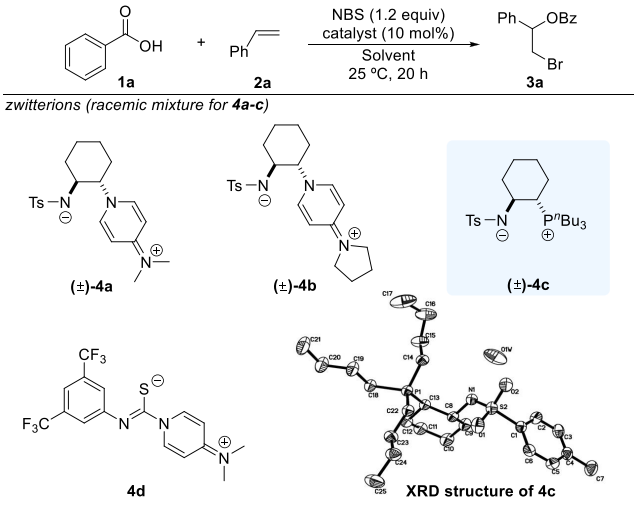
Table 1. Conditions Optimization[a]



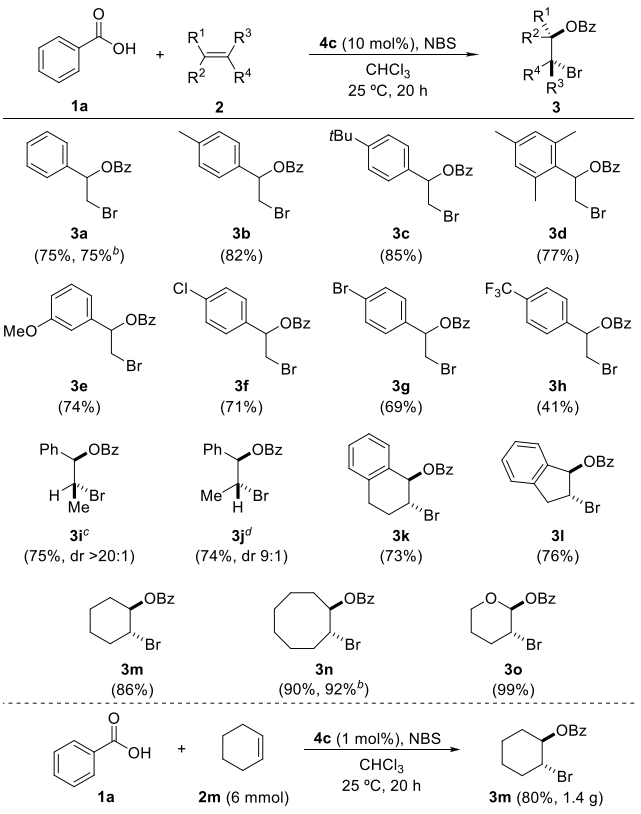
entry	catalyst	solvent	yield (%)[b]
1	none	PhMe	0
2	**4a**	PhMe	30
3	**4b**	PhMe	41
4	**4c**	PhMe	63
5	**4d**	PhMe	10
6	DABCO	PhMe	39
7	Et_3N	PhMe	20
8	Ph_3PS	PhMe	<5
9	P^nBu_3	PhMe	<5
10	CF_3COOH	PhMe	<5
11	$BF_3{\cdot}OMe_2$	PhMe	<5
12	**4c**	$CHCl_3$	75[c]

[a]Reactions were carried out with benzoic acid (**1a**) (0.2 mmol), catalyst (0.02 mmol), styrene (**2a**) (0.24 mmol), and NBS (0.24 mmol) in solvent (1.0 mL) for 20 h at 25 °C in the absence of light. [b]NMR yield using CH_2Br_2 as the internal standard. [c]Isolated yield.

desired product **3a** in fairly good yield (63%) (entry 4). Zwitterion **4d**, which was found to be effective in catalyzing the medium ring size bromolactonization,[22] was ineffective in catalyzing the reaction (entry 5). The catalytic performance of zwitterion (±)-**4c** was also found to be superior to other conventional catalysts such as Brønsted bases (DABCO, Et_3N) (entries 6 and 7), Lewis bases (Ph_3PS, P^nBu_3) (entries 8 and 9), Brønsted acid (CF_3COOH) (entry 10), and Lewis acid ($BF_3{\cdot}OMe_2$) (entry 11). This illustrates the unique role of zwitterion (±)-**4c** as an organocatalyst in the intermolecular bromoesterification. Followed by a brief solvent screening (see the Supporting Information), $CHCl_3$ was found to be the optimum (entry 12).

Substrate scope of this catalytic reaction was then examined. The scope of bromoesterification of benzoic acid (**1a**) with various olefins **2** is summarized in Scheme 1. In general, the reaction proceeded smoothly to give desired bromobenzoate **3** in good yield. Styrene-type olefins were first examined in this reaction (**2a**–**2l**). High reaction efficiency was observed with electron-rich styrenes (**2b**–**2e**). Sterically hindered olefin **2d** was also tolerated in this reaction. In comparison, electron-deficient styrenes (**2f**–**2h**) returned relatively in lower yields. Various disubstituted styrenes were also found to be compatible with this catalytic protocol (**2i**–**2l**). Excellent yields of products were also obtained for simple cyclic olefins

Scheme 1. Substrate Scope with Different Olefins[a]

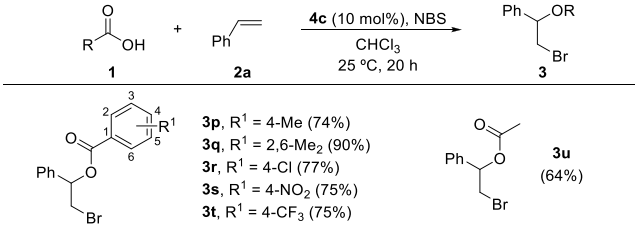


[a]Reactions were carried out with benzoic acid (**1a**) (0.2 mmol), **4c** (0.02 mmol), olefin **2** (0.24 mmol), and NBS (0.24 mmol) in $CHCl_3$ (1.0 mL) for 20 h at 25 °C in the absence of light. The yields were isolated yields. [b]The reactions were conducted with 0.01 mmol of catalyst **4c**. [c]*trans*-*β*-Methylstyrene was used as the substrate. [d]*cis*-*β*-Methylstyrene was used as the substrate.

(**2m**–**2o**). Quantitative yield of **3o** was obtained, presumably due to the highly electron-rich nature of dihydropyran **2o**. For particular substrates (**2a** and **2n**), the catalyst loading could be lowered to 5 mol % without deterioration of the reaction efficiency. In addition, as exemplified with **2m**, the reaction was readily scalable (gram-scale) with even lower catalyst loading (1 mol % of (±)-**4c**), and **3m** was obtained in good yield (80%).

Subsequently, the scope of bromoesterification of various carboxylic acids **1** with styrene (**2a**) was studied, and the results are summarized in Scheme 2. Benzoic acids **1** with

Scheme 2. Substrate Scope with Different Carboxylic Acids[a]



[a]Reactions were carried out with carboxylic acid **1** (0.2 mmol), **4c** (0.02 mmol), styrene (**2a**) (0.24 mmol), and NBS (0.24 mmol) in $CHCl_3$ (1.0 mL) for 20 h at 25 °C in the absence of light. The yields were isolated yields.

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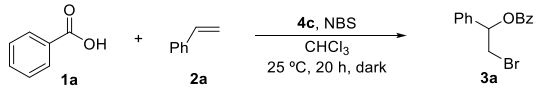
different electronic demands were examined and the reactions were found to be insensitive to electronic properties of the benzoic acids, giving **3p**−**3t** in good yields. It is worth noting that **3q** was furnished in excellent yield (90%) even when the sterically hindered 2,6-dimethylbenzoic acid was used as the reaction partner. Reaction using acetic acid also smoothly gave desired product **3u**.

During the catalyst study, an interesting phenomenon was observed which provided clues on the reaction mechanism. It was found that further increase of the catalyst loading beyond 10 mol % resulted in a deterioration of the catalytic performance (Table 2, entries 1−5). Since catalyst (±)-**4c**

Table 2. Effect of the Loading of 4c and BzOH[a]



1a 2a 3a

entry	4c (equiv)	BzOH (equiv)	yield (%)[b]
1	0.02	1	66
2	0.05	1	75
3	0.1	1	75
4	0.5	1	61
5	1	1	27
6	1	2	70
7	1	5	94
8	0	5	5

[a]Reactions were carried out with benzoic acid (0.2 mmol), catalyst, styrene (0.24 mmol), and NBS (0.24 mmol) in chloroform (1.0 mL) for 20 h at 25 °C in the absence of light. [b]Isolated yield.

bearing a Brønsted basic anionic toluenesulfonamide, a stoichiometric amount of (±)-**4c** might lead to a low effective concentration of benzoic acid (**1a**) due to the acid−base neutralization. On the basis of this rationale, it was hypothesized that a certain concentration of free carboxylic acid was essential in the catalytic cycle. Subsequent experiments of catalytic reactions were carried out using a stoichiometric amount of zwitterion (±)-**4c** together with additional benzoic acid (**1a**) to replenish the effective concentration of free benzoic acid. Addition of 2 equiv of benzoic acid (**1a**) rescued the reaction yield back to 70% (entry 6), while the use of 5 equiv of **1a** led to excellent yield (entry 7). The improvement did not originate from BzOH alone (entry 8). We suspect that carboxylic acid was not only acting as a nucleophile component but also assisting the catalysis.

^{1}H NMR studies between the reaction components were performed, and both carboxylic acid and NBS could interact independently with zwitterionic catalyst (±)-**4c** (Figure 1). When benzoic acid (**1a**) and (±)-**4c** were mixed in an equimolar ratio, simultaneous downfield shift of tosyl protons of **4c** and upfield shift of the aromatic protons of benzoic acid (**1a**) were observed, attributed to the occurrence of acid−base reaction between them (Figure 1b−d). The change of chemical shift of the α-proton in the phosphonium of (±)-**4c** (H^3) suggested the possibility of nonclassical hydrogen bonding (NCHB)[23] interaction between the phosphonium and the benzoate. In contrast, for the equimolar mixture of (±)-**4c** and NBS (Figure 1d−f), considerable chemical shifts of the protons (H^4) in NBS (upfield), the tosyl protons in (±)-**4c** (downfield) and the α-proton (H^3) of phosphonium in **1a**

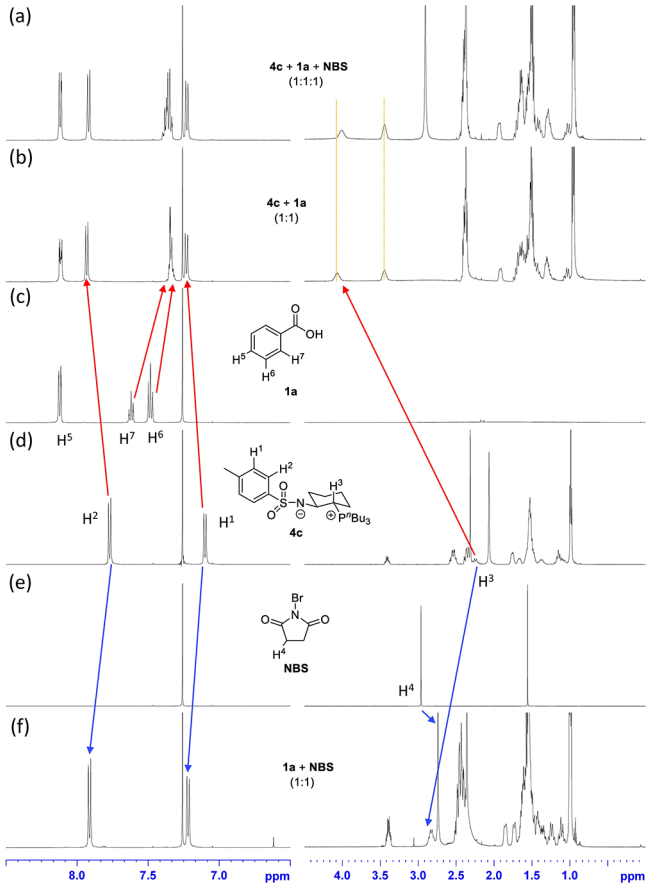


Figure 1. NMR experiments.

(downfield) were observed. This might indicate an interaction mode involving (1) the coordination of the tosylamide in (±)-**4c** to the electrophilic Br in NBS and (2) the NCHB interaction between the α-protons of phosphonium in (±)-**4c** and the carbonyl group in succinimide. An equimolar mixture of benzoic acid (**1a**), (±)-**4c**, and NBS was also analyzed (Figure 1a). As indicated by the slight change in the chemical shift of protons, the acid−base complex between **4c** and **1a** (Figure 1b) was interrupted by the existence of NBS. This might suggest that (±)-**4c** was competing with both benzoic acid (**1a**) and NBS.

A possible catalytic cycle is proposed based on the current experimental observations (Scheme 3). We rationalized that zwitterion (±)-**4c** could interact with carboxylic acid **1a** and NBS under equilibration to give species **C** (also evidenced from mass spectrometry, see the Supporting Information for details) with the exclusion of a succinimide molecule. This process could be achieved via: (1) protonation of (±)-**4c** by **1a** to give species **A** followed by the reaction with NBS or (2) bromination of (±)-**4c** by NBS to give species **B** followed by protonation of the succinimide anion. Species **C**, which contains electrophilic Br through the N−Br bond and nucleophilic carboxylate anion by NCHB interaction within the scaffold, could possibly facilitate the electrophilic addition of olefin **2a** via species **D**, yielding desired bromoester product **3a**. The un-ionized carboxylic acid was speculated to be a proton source to facilitate the formation of succinimide or a H-bond donor to activate species **D** as for Br^+ transfer to olefin.

In summary, we have developed an intermolecular bromoesterification of olefins using bifunctional zwitterionic

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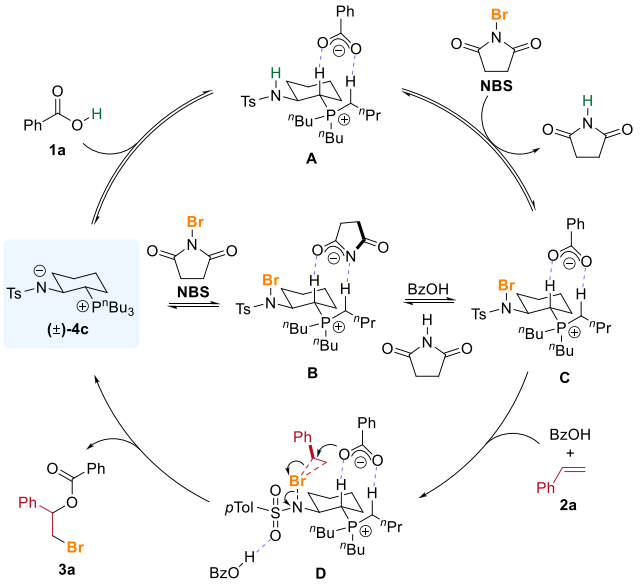
Scheme 3. Plausible Catalytic Cycle



catalysts bearing a cationic phosphonium and an anionic sulfonamide. The template effect provided by the zwitterion allowed efficient bromoesterification using an equimolar mixture of reactants. Further investigations on using the zwitterionic catalysts in other reactions including asymmetric haloesterification are underway.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acs.orglett.0c01928.

Experimental procedures and characterization data for all new compounds (PDF)

Accession Codes

CCDC 1949449 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge via www.ccdc.cam.ac.uk/data_request/cif, or by emailing data_request@ccdc.cam.ac.uk, or by contacting The Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK; fax: +44 1223 336033.

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Notes

The authors declare no competing financial interest.

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■ REFERENCES

(1) (a) Ranganathan, S.; Muraleedharan, K. M.; Vaish, N. K.; Jayaraman, N. *Tetrahedron* **2004**, *60*, 5273. (b) Denmark, S. E.; Burk, M. T. *Proc. Natl. Acad. Sci. U. S. A.* **2010**, *107*, 20655. (c) Jiang, X.; Liu, H. *Comprehensive Organic Synthesis II*; Elsevier: Waltham, MA, 2014; Vol. 4, p 412. (d) Chemler, S. R.; Bovino, M. T. *ACS Catal.* **2013**, *3*, 1076. (e) Rodríguez, F.; Fañanás, F. J.; Ma, S. *Handbook of Cyclization Reactions*; Wiley-VCH: Weinheim, 2010; Vol. 4, pp 951−990.

(2) Ashtekar, K. D.; Vetticatt, M.; Yousefi, R.; Jackson, J. E.; Borhan, B. *J. Am. Chem. Soc.* **2016**, *138*, 8114.

(3) (a) Rengevich, E. N.; Shilov, E. A.; Staninet, V. I. *Dokl. Akad. Nauk SSSR* **1962**, *146*, 111−114. (b) Staninets, V. I.; Shilov, E. A. *Russ. Chem. Rev.* **1971**, *40*, 272. (c) Williams, D. L. H.; Bienvenüe-Goetz, E.; Dubois, J. E. *J. Chem. Soc. B* **1969**, *0*, 517. (d) Bienvenüe-Goetz, E.; Dubois, J. E.; Pearson, D. W.; Williams, D. L. H. *J. Chem. Soc. B* **1970**, *0*, 1275. (e) Cambie, R. C.; Hayward, R. C.; Roberts, J. L.; Rutledge, P. S. *J. Chem. Soc., Perkin Trans. 1* **1974**, *1*, 1864. (f) Doi, J. T.; Luehr, G. W.; Delcarmen, D.; Lippsmeyer, B. C. *J. Org. Chem.* **1989**, *54*, 2764. (g) Snider, B. B.; Johnston, M. I. *Tetrahedron Lett.* **1985**, *26*, 5497. (h) Fahey, R. C. *Topics in Stereochemistry* **2007**, *3*, 237.

(4) Pimenta, L. S.; Gusevskaya, E. V.; Alberto, E. E. *Adv. Synth. Catal.* **2017**, *359*, 2297.

(5) Balkrishna, S. J.; Prasad, C. D.; Panini, P.; Detty, M. R.; Chopra, D.; Kumar, S. *J. Org. Chem.* **2012**, *77*, 9541.

(6) Ahmad, S. M.; Braddock, D. C.; Cansell, G.; Hermitage, S. A. *Tetrahedron Lett.* **2007**, *48*, 915.

(7) Ahmad, S. M.; Braddock, D. C.; Cansell, G.; Hermitage, S. A.; Redmond, J. M.; White, A. J. *Tetrahedron Lett.* **2007**, *48*, 5948.

(8) (a) Li, L.; Su, C.; Liu, X.; Tian, H.; Shi, Y. *Org. Lett.* **2014**, *16*, 3728. (b) Soltanzadeh, B.; Jaganathan, A.; Staples, R. J.; Borhan, B. *Angew. Chem., Int. Ed.* **2015**, *54*, 9517.

(9) (a) Li, G.; Fu, Q.; Zhang, X.; Jiang, J.; Tang, Z. *Tetrahedron: Asymmetry* **2012**, *23*, 245. (b) Cao, Y.-M.; Lentz, D.; Christmann, M. *J. Am. Chem. Soc.* **2018**, *140*, 10677.

(10) Shi, Y.; Wong, J.; Ke, Z.; Yeung, Y.-Y. *J. Org. Chem.* **2019**, *84*, 4017.

(11) Saikia, I. K.; Rajbongshi, K. K.; Phukan, P. K. *Tetrahedron Lett.* **2012**, *53*, 758.

(12) de Almeida, L.; Esteves, P.; de Mattos, M. *Synlett* **2006**, *2006*, 1515.

(13) Agrawal, M. K.; Adimurthy, S.; Ganguly, B.; Ghosh, P. K. *Tetrahedron* **2009**, *65*, 2791.

(14) Wan, C.; Song, R.-J.; Li, J.-H. *Org. Lett.* **2019**, *21*, 2800.

(15) Arai, T.; Horigane, K.; Suzuki, T. K.; Itoh, R.; Yamanaka, M. *Angew. Chem., Int. Ed.* **2020**, DOI: 10.1002/anie.202003886.

(16) For reviews, see (a) Brière, J.; Oudeyer, S.; Dalla, V.; Levacher, V. *Chem. Soc. Rev.* **2012**, *41*, 1696. (b) Brak, K.; Jacobsen, E. N.

Angew. Chem., Int. Ed. **2013**, *52*, 534. (c) Qian, D.; Sun, J. *Chem. - Eur. J.* **2019**, *25*, 3740. (d) Legros, F.; Oudeyer, S.; Levacher, V. *Chem. Rec.* **2017**, *17*, 429.

(17) For selected recent examples, see (a) Tsutsumi, Y.; Yamakawa, K.; Yoshida, M.; Ema, T.; Sakai, T. *Org. Lett.* **2010**, *12*, 5728. (b) Claraz, A.; Landelle, G.; Oudeyer, S.; Levacher, V. *Eur. J. Org. Chem.* **2013**, *2013*, 7693. (c) Chakraborty Ghosal, N.; Santra, S.; Das, S.; Hajra, A.; Zyryanov, G. V.; Majee, A. *Green Chem.* **2016**, *18*, 565. (d) Zhou, X.; Wu, Y.; Deng, L. *J. Am. Chem. Soc.* **2016**, *138*, 12297. (e) Xie, C.; Song, J.; Wu, H.; Zhou, B.; Wu, C.; Han, B. *ACS Sustainable Chem. Eng.* **2017**, *5*, 7086. (f) Liu, X.-F.; Li, X.-Y.; Qiao, C.; Fu, H.-C.; He, L.-N. *Angew. Chem., Int. Ed.* **2017**, *56*, 7425. (g) Uraguchi, D.; Torii, M.; Ooi, T. *ACS Catal.* **2017**, *7*, 2765. (h) Hasegawa, E.; Izumiya, N.; Miura, T.; Ikoma, T.; Iwamoto, H.; Takizawa, S.; Murata, S. *J. Org. Chem.* **2018**, *83*, 3921. (i) Ohmatsu, K.; Suzuki, R.; Furukawa, Y.; Sato, M.; Ooi, T. *ACS Catal.* **2020**, *10*, 2627.

(18) (a) Waser, M.; Novacek, J.; Gratzer, K. Cooperative Catalysis Involving Chiral Ion Pair Catalysts. In *Cooperative Catalysis: Designing Efficient Catalysts for Synthesis*; Peters, R., Ed.; Wiley-VCH: Germany, 2015; pp 197− 226. (b) Tian, S.; Chen, Y.; Hang, J.; Tang, L.; Mcdaid, P.; Deng, L. *Acc. Chem. Res.* **2004**, *37*, 621. (c) Chauhan, P.; Mahajan, S.; Kaya, U.; Hack, D.; Enders, D. *Adv. Synth. Catal.* **2015**, *357*, 253. (d) Liu, X.; Lin, L.; Feng, X. *Chem. Commun.* **2009**, 6145. (e) Brière, J.; Oudeyer, S.; Dalla, V.; Levacher, V. *Chem. Soc. Rev.* **2012**, *41*, 1696. (f) Brak, K.; Jacobsen, E. N. *Angew. Chem., Int. Ed.* **2013**, *52*, 534. (g) Phipps, R. J.; Hamilton, G. L.; Toste, F. D. *Nat. Chem.* **2012**, *4*, 603.

(19) McNaught, A. D.; Wilkinson, A. *IUPAC. Compendium of Chemical Terminology*, 2nd ed.; Blackwell Scientific Publications: Oxford, 1997.

(20) Lam, Y.-P.; Wang, X.; Tan, F.; Ng, W.-H.; Tse, Y.-L. S.; Yeung, Y.-Y. *ACS Catal.* **2019**, *9*, 8083.

(21) Hou, X.-L.; Fan, R.-H.; Dai, L.-X. *J. Org. Chem.* **2002**, *67*, 5295.

(22) (a) Cheng, Y. A.; Chen, T.; Tan, C. K.; Heng, J. J.; Yeung, Y.-Y. *J. Am. Chem. Soc.* **2012**, *134*, 16492. (b) Xiong, X.; Tan, F.; Yeung, Y.-Y. *Org. Lett.* **2017**, *19*, 4243.

(23) (a) Johnston, R. C.; Cheong, P. H.-Y. *Org. Biomol. Chem.* **2013**, *11*, 5057. (b) Berg, L.; Mishra, B. K.; Andersson, C. D.; Ekström, F.; Linusson, A. *Chem. - Eur. J.* **2016**, *22*, 2672. (c) Molina, P.; Zapata, F.; Caballero, A. *Chem. Rev.* **2017**, *117*, 9907. (d) Ajitha, M. J.; Huang, K.-W. *Synthesis* **2016**, *48*, 3449.

https://dx.doi.org/10.1021/acs.orglett.0c01928
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