JOC The Journal of Organic Chemistry

Article

pubs.acs.org/joc

Direct Conversion of *N*-Alkoxyamides to Carboxylic Esters through Tandem NBS-Mediated Oxidative Homocoupling and Thermal Denitrogenation

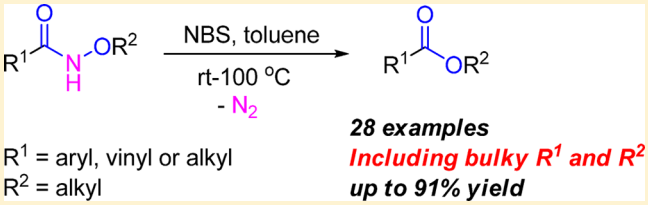
Ningning Zhang,[†] Rui Yang,[†] Daisy Zhang-Negrerie,[†] Yunfei Du,*[,†,‡] and Kang Zhao*[,†]

[†]Tianjin Key Laboratory for Modern Drug Delivery & High-Efficiency, School of Pharmaceutical Science and Technology, Tianjin University, Tianjin 300072, China

[‡]Synergetic Innovation Center of Chemical Science and Engineering (Tianjin), Tianjin 300072, China

Supporting Information

ABSTRACT: Treatment of *N*-alkoxyamides with NBS in toluene was found to conveniently afford the corresponding carboxylic esters, including those bearing a bulky or long-chain substituent, in satisfactory to excellent yields. This approach not only represents a convenient and economic approach to a direct transformation of an alkoxyamide moiety into the carboxylic ester functional group, via oxidative homocoupling and the subsequent thermal denitrogenation, but also facilitates the synthesis of sterically hindered carboxylic esters.



INTRODUCTION

The ester moiety is an important functional group that has found wide occurrences in polymers, pharmaceutical agents and biologically relevant natural products. Although many methods have been reported for the synthesis of esters,[1] formation of hindered esters continues to remain as a challenge. In traditional esterification reactions, a bulky group on either the carboxylic acid or the alcohol significantly hampers the reaction.[2−4] This effect is also observed in the reactions between acid chlorides and alcohols.[2−4] Consequently, special reagents and procedures are normally required for achieving these sterically bulky carboxylic esters.[5] Undoubtedly, development of novel methods for efficient synthesis of hindered esters is in high demand.

In contrast to the formation of carboxylic esters, it has been reported that bulky substituents do not hamper the synthesis of hydroxamic esters, either by reactions of acid chlorides with alkoxyamines or by alkylations of sodium salts of hydroxamic acids.[6] In this regard, a direct conversion of *N*-alkoxyamides to carboxylic esters as an efficient strategy to the synthesis of hindered esters can be envisaged. A literature survey[7−10] shows that *N*-alkoxyamides **1** can be converted to *N*,*N*-bis-heteroatom-substituted amides **A**, which are unstable and can thermally decompose to generate the corresponding esters. However, heavy metal oxidants, such as nickel(IV) peroxide hydrate ($NiO_2·H_2O$),[7] ceric ammonium nitrate (CAN),[7] silver oxide (Ag_2O)[8] or lead(IV) acetate ($Pb(OAc)_4$)[9,10] have always been used as oxidants for the dimerization reactions (Figure 1, path a). In 2002, Glover and co-workers[6] reported that *N*-alkoxyamides, after being converted to *N*-chlorohydroxamates, could react with sodium azide to furnish the ester products via Heron rearrangement (Figure 1, path b). It is worth noting that

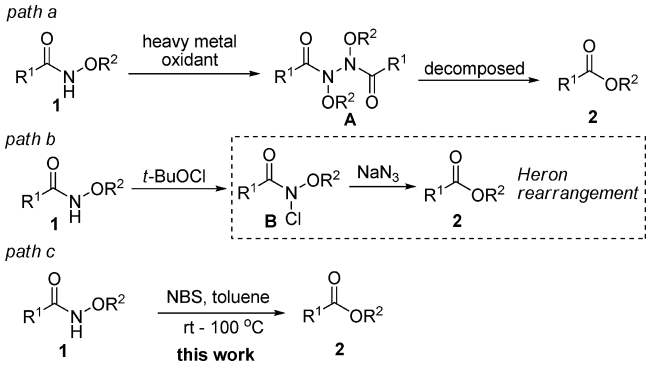


Figure 1. Methods for conversions of *N*-alkoxyamides to hindered esters.

this attractive two-step method could be well applied to the synthesis of some highly hindered esters. In this article, we report a more convenient one-step conversion of alkoxyamides to carboxylic esters through reactions of alkoxyamides with the readily available NBS in toluene (Figure 1, path c). Consistent with Glover's findings,[6] this alternative approach also provides accesses to sterically hindered esters. The advantages of the current method, in comparison to the existing methods, are its directness of one step and low cost of the reagents.

RESULTS AND DISCUSSION

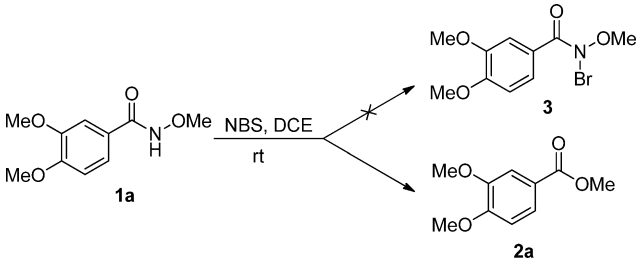
Our original research objective was focused on forming *N*-bromo-*N*-methoxybenzamide **3** and then to study its role as a

Received: July 2, 2013
Published: August 8, 2013

   dx.doi.org/10.1021/jo401435v | J. Org. Chem. 2013, 78, 8705−8711

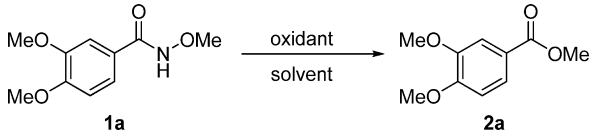
nitrenium ion precursor in some intermolecular electrophilic substitution reactions[11] that we were interested in. Knowing the fact that α,β-unsaturated *N*-acyl-amino acid ester could be converted to its *N*-bromo product mediated by NBS,[12] we applied the method to have *N*-methoxybenzamide **1a** reacting with NBS. However, to our surprise, when **1a** was treated with NBS in DCE at room temperature, ester **2a** was formed in 77% yield, with trace of the desired compound **3** formed (Scheme 1). Although unexpected, this new finding led us to establish a novel method for the synthesis of carboxylic ester compounds from the corresponding alkoxyamides.

Scheme 1. Discovery of the Conversion of *N*-Methoxybenzamide 1a to Ester 2a



Considering that the yield obtained for **2a** was somewhat low, **1a** was used as a model substrate to further optimize the reaction conditions. Solvent-screening experiments revealed that the reaction could occur in polar as well as nonpolar solvents (Table 1, entries 1−8), and the reaction in toluene gave the best yield within a relatively short period of time (Table 1, entry 8). When the reaction temperature was raised to 60 °C, the reaction was completed in 0.3 h with negligible decrease in yield (Table 1, entry 9). A parallel experiment (Table 1, entry 10) of using 0.5 equiv of NBS was carried out to determine the molar ratio of each reactant, and the result showed that close to 50 mol % of **1a** was recovered. This finding clearly indicated that at least 1.0 equiv of NBS was necessary for the total conversion of **1a** to **2a**. Other *N*-halosuccinimides (NCS and NIS) were also tested, and the results showed that they gave inferior yields when compared with NBS (Table 1, entries 11 and 12).

Table 1. Optimization of Reaction Conditions[a]



entry	oxidant	solvent	temp (°C)	time (h)	yield (%)[b]
1	NBS	DCE	rt	6	77
2	NBS	MeCN	rt	6	47
3	NBS	EtOAc	rt	6	79
4	NBS	MeOH	rt	6	88
5	NBS	dioxane	rt	6	85
6	NBS	DMF	rt	6	82
7	NBS	THF	rt	6	83
8	NBS	toluene	rt	3	94
9	NBS	toluene	60	0.3	91
10[c]	NBS	toluene	60	0.3	45
11	NIS	toluene	60	0.3	77
12	NCS	toluene	reflux	2	60

[a]Reaction conditions: **1a** (1.0 mmol), oxidant (1.0 mmol) in solvent (10 mL) unless otherwise stated. [b]Isolated yields. [c]0.5 equiv of NBS was used.

With the optimal reaction conditions (Table 1, entry 9) in hand, the scope of this newly established NBS-mediated direct conversion of alkoxyamides to carboxylic esters was explored. The *N*-methoxybenzamide derivatives **1b−1g**, bearing either aromatic electron-donating or electron-withdrawing groups, could all be converted to the corresponding esters by the method. With the increasing of the electron-withdrawing ability of the aromatic substituent, the yield of the reaction decreased (Table 2, entries 1−7). When the substrate bears a nitro group, other than the relatively lower yield, the reaction needed a longer reaction time for a complete conversion (Table 2, entry 7). The analogous *N*-benzyloxybenzamides **1h−1j** could also be converted to the corresponding benzyl benzoates **2h−2j** under the described conditions, which indicates that the R^2 group is not restricted only to the methyl group, but can also be extended to other alkyl groups as well (Table 2, entries 8−10). Replacing the phenyl ring with a heterocyclic thienyl ring in the substrate does not hamper the reaction, and the desired product **2k** could be obtained in moderate yield (Table 2, entry 11). Furthermore, *N*-methoxycinnamamides could also be converted to the corresponding carboxylic esters by the same method, with the alkenyl moiety being well tolerated during the process (Table 2, entries 12 and 13). Finally, the method was also applicable to the substrate bearing aliphatic carboxylic amides, with the products being achieved in acceptable to moderate yields (Table 2, entries 14−17). For this class of substrates, the electron-withdrawing groups in the aromatic ring on either the acid or the alcohol side do not have an obvious impact on the yield. Furthermore, a chlorine atom in the substrate could also be well tolerated, albeit the desired product was obtained in a slightly lower yield (Table 2, entry 18).

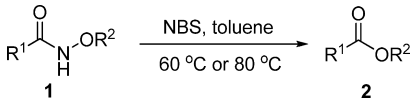
An important application of this methodology is in the synthesis of hindered esters, which is known to be difficult to obtain by the classic methods.[2−4,6] Our experiments show that when R^2 is a bulky *t*-butyl group, substrates **1aa−1ac**, bearing an aromatic or benzyl R^1 group, rendered the corresponding esters **2aa−2ac** in moderate to good yields (Table 3, entries 1−3). When the R^2 substituent is a long-chain alkyl group containing 12 carbons, the reaction afforded the desired products in excellent yield (Table 3, entries 4 and 5). Besides, for substrates bearing a bulky R^1 group, the reaction also delivered the desired products in high yields (Table 3, entries 6−7). Most delightedly, we found this method could be applicable to the synthesis of the esters bearing both bulky R^1 and R^2 groups (Table 3, entries 8−10).

It is worth noting that *N*-methoxybenzamide **1c**, bearing a bromo-substituted phenyl group, was converted to its homodimer **3c** if the reaction was run at room temperature. The isolated homodimer **3c**, upon being heated in toluene at 80 °C for 1 h, afforded the benzoate **2c** in 90% yield. The observation of **3c** demonstrates that the reaction adopts a cascade sequence involving the oxidative homocoupling step, and followed by the subsequent thermal denitrogenation (Scheme 2).

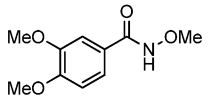
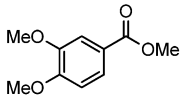
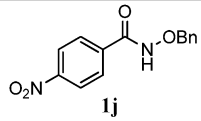
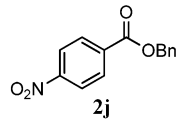
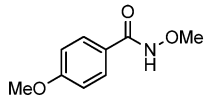
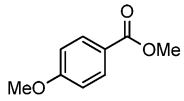
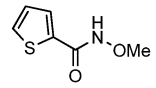
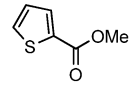
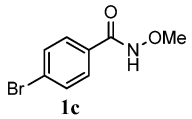
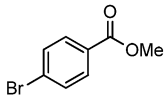
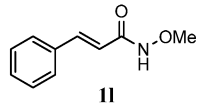
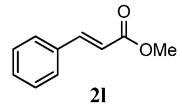
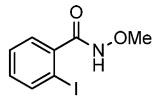
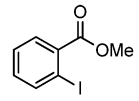
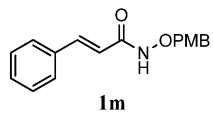
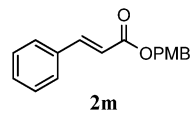
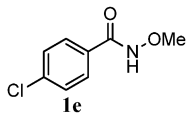
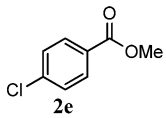
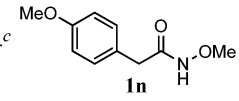
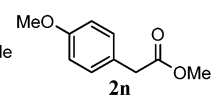
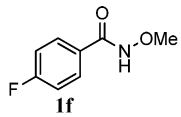
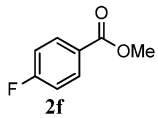
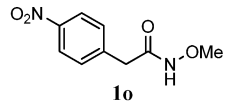
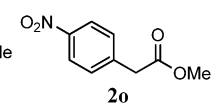
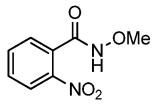
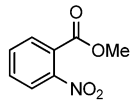
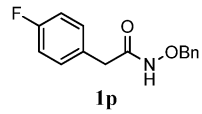
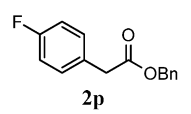
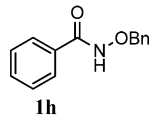
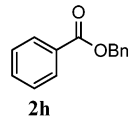
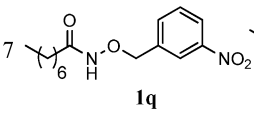
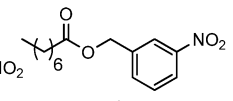
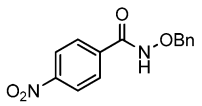
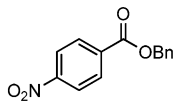
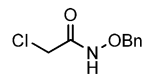
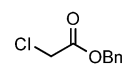
On the basis of the previous reports in literature[7,11g] as well as our own studies, we propose here a possible mechanism for this oxidative homocoupling and thermal denitrogenation process (Scheme 3). Since at least 1 equiv of NBS was needed, we postulate that alkoxyamide **1** first reacted with NBS to afford *N*-bromohydroxamate **B**. Then the N−Br bond in

dx.doi.org/10.1021/jo401435v | J. Org. Chem. 2013, 78, 8705−8711

Table 2. Conversion of *N*-Alkoxyamides to Carboxylic Esters Mediated by NBS[a]



1 2

entry	substrate	product	time (h)	yield (%)[b]	entry	substrate	product	time (h)	yield (%)[b]
1	 **1a**	 **2a**	0.3	91	10	 **1j**	 **2j**	2	72
2	 **1b**	 **2b**	0.3	88	11	 **1k**	 **2k**	2	63
3	 **1c**	 **2c**	1	85	12[c]	 **1l**	 **2l**	1	85
4	 **1d**	 **2d**	1	76	13[c]	 **1m**	 **2m**	1	61
5	 **1e**	 **2e**	1	60	14[c]	 **1n**	 **2n**	1	53
6	 **1f**	 **2f**	1	50	15[c]	 **1o**	 **2o**	2	72
7	 **1g**	 **2g**	2	61	16[c]	 **1p**	 **2p**	5	72
8	 **1h**	 **2h**	1	75	17	 **1q**	 **2q**	1	76
9	 **1i**	 **2i**	1	62	18	 **1r**	 **2r**	5	43

[a]Reaction conditions: **1** (1.0 mmol) and NBS (1.0 mmol) in toluene (10 mL) at 60 °C unless otherwise stated. [b]Isolated yields. [c]The reaction was stirred at 80 °C.

intermediate **B** underwent the homolytic cleavage to give the *N*-centered radical species,[11g] which dimerized to form *N*,*N*′-diacyl-*N*,*N*′- dialkoxyhydrazine **C**, with the concurrent release of a molecular Br_2 (formed from the released bromine radicals). As intermediate **C** is thermally unstable, it decomposed to generate ester **2** and nitrene **D** by a 1,1-elimination pathway.[7] Finally, nitrene **D** decomposed to afford nitrogen and another molecule of ester **2**.[7] For all the above reactions studied, it was observed that the reaction solution displayed a dark red color (likely due to the generated Br_2) at the early stage, which gradually diminished along the progress of the reaction. At the same time, benzyl bromide **4** was detected being formed in all the reactions as a side product, which obviously resulted from the reaction between the solvent toluene and the generated Br_2.

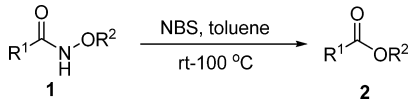
In summary, we have demonstrated a novel methodology for the direct conversion of alkoxyamides to carboxylic esters via NBS-mediated oxidative homocoupling and thermal denitrogenation reactions. The features of the present method include the ready availability of the starting materials, the mild reaction conditions, and most significantly, its economic application to the synthesis of a wide range of sterically hindered esters.

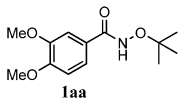
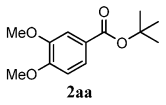
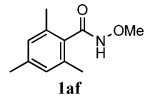
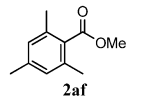
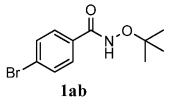
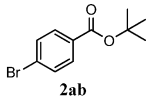
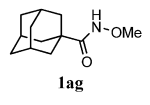
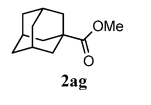
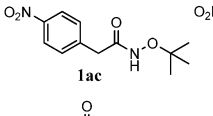
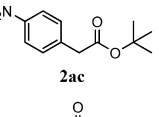
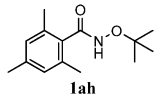
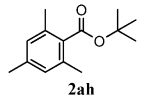
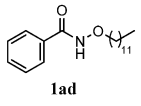
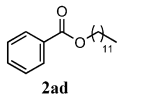
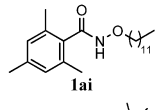
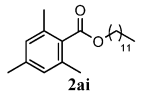
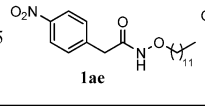
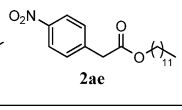
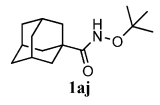
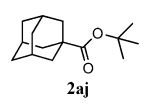
■ EXPERIMENTAL SECTION

I. General Information. ^1H and ^{13}C NMR spectra were recorded on a 600 MHz spectrometer (150 MHz for ^{13}C NMR) at 25 °C. Chemical shift values were given in ppm and referred to the internal standard TMS set as 0.00 ppm. The peak patterns were indicated as follows: s, singlet; d, doublet; t, triplet; q, quartet; qui, quintet; m,

dx.doi.org/10.1021/jo401435v | J. Org. Chem. 2013, 78, 8705−8711

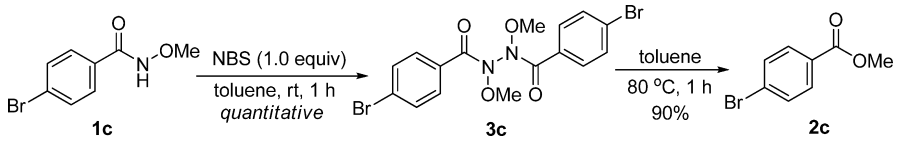
Table 3. Conversions of *N*-Alkoxyamides to Hindered Esters Mediated by NBS[a]



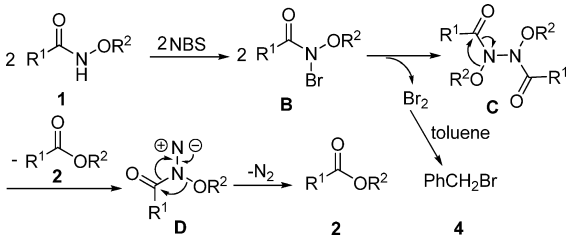
entry	substrate	product	time (h)	yield (%)[b]	entry	substrate	product	time (h)	yield (%)[b]
1[c]	 1aa	 2aa	12	84	6[d]	 1af	 2af	1	85
2	 1ab	 2ab	1	50	7[c]	 1ag	 2ag	12	85
3	 1ac	 2ac	1	70	8	 1ah	 2ah	1	70
4	 1ad	 2ad	1	90	9	 1ai	 2ai	1	84
5	 1ae	 2ae	1	75	10[c]	 1aj	 2aj	12	42

[a]Reaction conditions: **1** (1.0 mmol) and NBS (1.0 mmol) in toluene (10 mL) at 80 °C. [b]Isolated yields. [c]The reaction was stirred at rt. [d]The reaction was stirred at 100 °C.

Scheme 2. Formation of the Homodimer 3c and Its Thermal Decomposition



Scheme 3. Proposed Reaction Pathway



multiplet; td, triplet of doublets; and dd, doublet of doublets. The coupling constants, *J*, are reported in Hertz (Hz). High resolution mass spectrometry (HRMS) was obtained on a Q-TOF micro-spectrometer. Melting points were determined with a micromelting point apparatus without corrections. TLC plates were visualized by UV fluorescence quenching and $KMnO_4$ staining. Reagents and solvents were purchased as reagent grade and were used without further purification. All reactions were performed in standard glassware and heated at 70 °C for 3 h before use. Flash column chromatography was performed over silica gel 200−300 mesh, and the eluent was a mixture of ethyl acetate (EA) and petroleum ether (PE).

II. Preparation of Alkoxyamides 1. All the known amides **1a**,[13] **1b−d**,[14] **1e,f**,[15] **1h**,[13] **1j**,[16] **1k**,[15] **1l**,[17] **1n**,[11] **1o**,[18] **1r**,[19] **1af**,[20] **1ag**,[7] and **1aj**[7] were prepared in accordance with the indicated literature procedures.

Amides **1g**, **1i**, **1m**, **1p**, **1q**, **1aa−1ae**, **1ah**, and **1ai** were prepared by the following known or modified procedures.

General Procedure A.[14] To the carboxylic acid (10 mmol) was added thionyl chloride (20 mmol) followed by a catalytic amount of DMF (1 drop). The mixture was stirred at 60 °C until completion (ca. 3 h). The solvent was then removed under reduced pressure to afford the crude acid chloride. Alkoxyamine hydrochloride (11 mmol) was added to a mixture of K_2CO_3 (20 mmol) in a 2:1 mixture of EA:H_2O (0.2 M). The resulting solution was cooled to 0 °C followed by dropwise addition of the crude acid chloride dissolved in EA (5 mL). The reaction was allowed to stir for 4 h while reaching room temperature. The two layers were separated, and the aqueous phase was extracted with EA (20 mL × 2). The combined organic phase was dried over anhydrous Na_2SO_4, filtered, and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel to give the desired products.

General Procedure B. To the carboxylic acid (10 mmol) was added thionyl chloride (20 mmol) followed by a catalytic amount of DMF (1 drop). The reaction was then stirred at 60 °C until completion (ca. 3 h). The solvent was then removed under reduced pressure to afford the crude acid chloride. TEA (22 mmol) was added to a mixture of alkoxyamine hydrochloride (11 mmol) in DCE (0.2 M). The resulting mixture was cooled to 0 °C followed by dropwise addition of the crude acid chloride dissolved in DCE (5 mL). The reaction was allowed to stir at room temperature overnight. The reaction mixture was then diluted with DCM (40 mL) and washed with water (40 mL) and brine (40 mL). The organic phase was dried over anhydrous Na_2SO_4, filtered, and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel to give the desired products.

The novel amides thus obtained were characterized as follows:

dx.doi.org/10.1021/jo401435v | J. Org. Chem. 2013, 78, 8705−8711

*N-Methoxy-2-nitrobenzamide (**1g**).* Following the general procedure A, amide **1g** was isolated as a light yellow solid. Yield: 1.72 g, 88%; mp 88−89 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ (mixture of two rotamers) 8.57 (s, 1H), 8.14 (d, J = 6.6 Hz, 1H), 7.72 (s, 1H), 7.64 (t, J = 7.5 Hz, 1H), 7.55 (d, J = 6.6 Hz, 1H), 3.94 (s, 2H), 3.44 (s, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 164.4, 146.3, 133.8, 131.0, 129.4, 129.1, 124.5, 63.6; HRMS (ESI) m/z calcd for $C_8H_8N_2NaO_4^+$ [M + Na^+] 219.0376, found 219.0357.

*N-(Benzyloxy)-3-methylbenzamide (**1i**).* Following the general procedure A, amide **1i** was isolated as a white solid. Yield: 2.17 g, 90%; mp 89−90 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.88 (s, 1H), 7.51 (s, 1H), 7.46−7.40 (m, 3H), 7.38−7.33 (m, 3H), 7.29 (d, J = 7.5 Hz, 1H), 7.25 (m, 1H), 5.01 (s, 2H), 2.34 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 166.4, 138.5, 135.4, 132.7, 131.8, 129.3, 128.7, 128.6, 128.5, 127.9, 124.1, 78.3, 21.3; HRMS (ESI) m/z calcd for $C_{15}H_{15}NNaO_2^+$ [M + Na^+] 264.0995, found 264.0971.

*N-(4-Methoxybenzyloxy)cinnamamide (**1m**).* Following the general procedure B, amide **1m** was isolated as a white solid. Yield: 1.56 g, 55%; mp 117−118 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.68 (d, J = 15.7 Hz, 1H), 7.46 (s, 2H), 7.33 (d, J = 8.2 Hz, 5H), 6.87 (d, J = 8.3 Hz, 2H), 6.34 (br s, 1H), 4.90 (s, 2H), 3.76 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 164.7, 159.9, 141.5, 134.8, 131.0, 129.8, 128.8, 128.0, 127.5, 117.5, 113.9, 78.0, 55.2; HRMS (ESI) m/z calcd for $C_{17}H_{17}NNaO_3^+$ [M + Na^+] 306.1101, found 306.1088.

*N-(Benzyloxy)-2-(4-fluorophenyl)acetamide (**1p**).* Following the general procedure A, amide **1p** was isolated as a white solid. Yield: 2.43 g, 94%; mp 103−104 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ (mixture of two rotamers) 8.52 (s, 0.77H), 8.09 (s, 0.23H), 7.31 (m, 5H), 7.14 (br s, 2H), 6.96 (m, 2H), 4.85 (s, 1.55H), 4.74 (s, 0.45H), 3.62 (s, 0.45H), 3.36 (s, 1.55H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 168.7, 162.0 (d, J_{C-F} = 245.6 Hz), 135.2, 130.7(d, J_{C-F} = 6.6 Hz), 130.1, 129.2, 128.7, 128.5, 115.5 (d, J_{C-F} = 21.3 Hz), 78.0, 39.3; HRMS (ESI) m/z calcd for $C_{15}H_{14}FNNaO_2^+$ [M + Na^+] 282.0901, found 282.0867.

*N-(3-Nitrobenzyloxy)octanamide (**1q**).* Following the general procedure B, amide **1q** was isolated as a white solid. Yield: 1.47 g, 50%; mp 110−111 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.26 (s, 1H), 8.21 (d, J = 7.5 Hz, 1H), 7.77 (d, J = 5.8 Hz, 1H), 7.57 (t, J = 7.7 Hz, 1H), 5.01 (s, 2H), 2.09 (s, 2H), 1.66−1.58 (m, 2H), 1.26 (m, 8H), 0.87 (t, J = 6.8 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 171.8, 148.2, 137.7, 134.9, 129.5, 123.5, 123.4, 76.7, 33.1, 31.6, 29.1, 28.9, 25.4, 22.6, 14.0; HRMS (ESI) m/z calcd for $C_{15}H_{22}N_2NaO_4^+$ [M + Na^+] 317.1472, found 317.1432.

*N-tert-Butoxy-3,4-dimethoxybenzamide (**1aa**).* Following the general procedure A, amide **1aa** was isolated as a white solid. Yield: 1.99 g, 79%; mp 114−115 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.38 (d, J = 1.7 Hz, 1H), 7.31 (d, J = 8.2 Hz, 1H), 6.84 (d, J = 8.3 Hz, 1H), 3.91 (d, J = 1.7 Hz, 6H), 1.33 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 167.4, 151.4, 148.9, 124.9, 120.1, 110.7, 110.3, 82.1, 77.4, 77.2, 77.0, 55.9, 55.9, 55.9, 55.9, 26.4; HRMS (ESI) m/z calcd for $C_{13}H_{19}NNaO_4^+$ [M + Na^+] 276.1206, found 276.1177.

*4-Bromo-N-tert-butoxybenzamide (**1ab**).* Following the general procedure A, amide **1ab** was isolated as a white solid. Yield: 2.25 g, 83%; mp 133−134 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.60 (s, 1H), 7.62 (d, J = 8.3 Hz, 2H), 7.53 (d, J = 8.4 Hz, 2H), 1.32 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 167.0, 131.7, 131.3, 128.9, 126.4, 82.5, 26.5; HRMS (ESI) m/z calcd for $C_{11}H_{14}{}^{79}BrNNaO_2^+$ [M + Na^+] 294.0100, found 294.0088.

*N-tert-Butoxy-2-(4-nitrophenyl)acetamide (**1ac**).* Following the general procedure A, amide **1ac** was isolated as a light yellow solid. Yield: 1.58 g, 63%; mp 131−132 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ (mixture of two rotamers) 8.19 (d, J = 7.9 Hz, 2H), 7.69 (br s, 1H), 7.48 (br s, 2H), 3.86 (s, 0.9H), 3.59 (s, 1.1H), 1.31 (s, 4H), 1.25 (s, 5H); ^{13}C NMR (150 MHz, $CDCl_3$) δ (* denotes minor rotamer peaks) 168.5, 147.0, 142.5, 142.08*, 130.6*, 130.0, 123.6, 82.5, 82.12*, 40.0, 38.4*, 26.3; HRMS (ESI) m/z calcd for $C_{12}H_{16}N_2NaO_4^+$ [M + Na^+] 275.1002, found 275.0980.

*N-(Dodecyloxy)benzamide (**1ad**).* Following the general procedure A, amide **1ad** was isolated as a white solid. Yield: 2.68 g, 88%; mp 49−50 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.74 (d, J = 7.2 Hz, 2H), 7.50 (t, J = 7.2 Hz, 1H), 7.41 (t, J = 7.2 Hz, 2H), 4.01 (t, J = 6.7 Hz, 2H), 1.73−1.67 (m, 2H), 1.35−1.23 (m, 18H), 0.88 (t, J = 7.0 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 166.1, 132.0, 131.9, 128.7, 127.0, 31.9, 29.7, 29.6, 29.6, 29.6, 29.4, 29.4, 28.1, 25.9, 22.7, 14.1; HRMS (ESI) m/z calcd for $C_{19}H_{31}NNaO_2^+$ [M + Na^+] 328.2247, found 328.2216.

*N-(Dodecyloxy)-2-(4-nitrophenyl)acetamide (**1ae**).* Following the general procedure A, amide **1ae** was isolated as a yellow solid. Yield: 1.63 g, 45%; mp 91−92 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ (mixture of two rotamers) 8.20 (d, J = 8.5 Hz, 2H), 8.05 (br s, 1H), 7.47 (d, J = 8.5 Hz, 2H), 3.90 (s, 1H), 3.86 (s, 2H), 3.56 (s, 1H),1.63 (s, 2H), 1.45−1.16 (m, 18H), 0.88 (t, J = 7.0 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ (* denotes minor rotamer peaks) 167.2, 147.1, 141.9, 130.5*, 130.1, 123.7, 78.0, 39.8, 38.3*, 31.9, 29.6, 29.6, 29.6, 29.5, 29.4, 29.3, 28.0, 25.8, 22.7, 14.1; HRMS (ESI) m/z calcd for $C_{20}H_{32}N_2NaO_4^+$ [M + Na^+] 387.2254, found 387.2229.

*N-tert-Butoxy-2,4,6-trimethylbenzamide (**1ah**).* Following the general procedure B, amide **1ah** was isolated as a white solid. Yield: 1.28 g, 55%; mp 140−141 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.77 (s, 1H), 6.84 (s, 2H), 2.32 (s, 6H), 2.27 (s, 3H), 1.36 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 169.4, 139.1, 135.2, 131.7, 128.2, 82.2, 26.6, 21.1, 19.3; HRMS (ESI) m/z calcd for $C_{14}H_{20}NNaO_2^+$ [M + Na^+] 258.1465, found 258.1425.

*N-(Dodecyloxy)-2,4,6-trimethylbenzamide (**1ai**).* Following the general procedure B, amide **1ai** was isolated as a white solid. Yield: 2.01 g, 58%; mp 51−52 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.35 (s, 1H), 6.81 (s, 2H), 4.03 (t, J = 6.8 Hz, 2H), 2.27 (d, J = 7.5 Hz, 9H), 1.75−1.67 (m, 2H), 1.43−1.21 (m, 18H), 0.88 (t, J = 6.8 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 167.6, 139.2, 135.3, 130.9, 128.2, 31.9, 29.7, 29.6, 29.6, 29.5, 29.5, 29.4, 28.1, 25.8, 22.7, 21.1, 18.9, 14.1; HRMS (ESI) m/z calcd for $C_{22}H_{37}NNaO_2^+$ [M + Na^+] 370.2717, found 370.2710.

III. Conversion of Alkoxyamides 1 to Esters 2. *General Procedure C.* A solution of **1** (1.0 mmol) and NBS (1.0 mmol) in toluene (10 mL) was stirred at the designated temperature. The reaction was monitored by TLC. After the reaction was completed, the reaction mixture was allowed to cool to room temperature, and EA (20 mL) was added. The resulting mixture was washed with saturated aqueous $Na_2S_2O_3$ (10 mL). The organic layer was dried over anhydrous Na_2SO_4, filtered, and removed under reduced pressure. The residue was purified by flash column chromatography on silica gel.

*Methyl 3,4-dimethoxybenzoate (**2a**).*[21] Following the general procedure C, **2a** was isolated as a white solid. Yield: 178 mg, 91%; mp 57−58 °C (lit.[21] 57−59 °C); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.68 (dd, J = 8.4, 1.7 Hz, 1H), 7.55 (d, J = 1.5 Hz, 1H), 6.89 (d, J = 8.4 Hz, 1H), 3.93 (d, J = 2.0 Hz, 6H), 3.90 (s, 3H).

*Methyl 4-methoxybenzoate (**2b**).*[22] Following the general procedure C, **2b** was isolated as a white solid. Yield: 146 mg, 88%; mp 47−48 °C. (lit.[22] 47−49 °C); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.99 (d, J = 8.8 Hz, 2H), 6.91 (d, J = 8.8 Hz, 2H), 3.88 (s, 3H), 3.85 (s, 3H).

*Methyl 4-bromobenzoate (**2c**).*[21] Following the general procedure C, **2c** was isolated as a white solid. Yield: 182 mg, 85%; mp 73−74 °C (lit.[21] 74−76 °C); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.90 (d, J = 8.5 Hz, 2H), 7.58 (d, J = 8.5 Hz, 2H), 3.91 (s, 3H).

*Methyl 2-iodobenzoate (**2d**).*[23] Following the general procedure C, **2d** was isolated as a light yellow oil. Yield: 199 mg, 76%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.99 (dd, J = 7.9, 0.9 Hz, 1H), 7.80 (dd, J = 7.8, 1.6 Hz, 1H), 7.40 (td, J = 7.7, 1.0 Hz, 1H), 7.15 (td, J = 7.7, 1.7 Hz, 1H), 3.93 (s, 3H).

*Methyl 4-chlorobenzoate (**2e**).*[24] Following the general procedure C, **2e** was isolated as a light yellow oil. Yield: 102 mg, 60%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.97 (d, J = 8.5 Hz, 2H), 7.41 (d, J = 8.5 Hz, 2H), 3.92 (s, 3H).

*Methyl 4-fluorobenzoate (**2f**).*[22] Following the general procedure C, **2f** was isolated as a light yellow oil. Yield: 77 mg, 50%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.09−8.03 (m, 2H), 7.11 (t, J = 8.6 Hz, 2H), 3.91 (s, 3H).

*Methyl 2-nitrobenzoate (**2g**).*[25] Following the general procedure C, **2g** was isolated as a light yellow oil. Yield: 110 mg, 61%, light yellow oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.91 (d, J = 8.0 Hz, 1H), 7.75 (dd,

dx.doi.org/10.1021/jo401435v | J. Org. Chem. 2013, 78, 8705−8711

J = 7.6, 1.3 Hz, 1H), 7.68 (td, J = 7.5, 1.0 Hz, 1H), 7.64 (td, J = 7.8, 1.4 Hz, 1H), 3.93 (s, 3H).

*Benzyl benzoate (**2h**).*[26] Following the general procedure C, **2h** was isolated as a colorless oil. Yield: 159 mg, 75%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.08 (d, J = 7.8 Hz, 2H), 7.55 (t, J = 7.4 Hz, 1H), 7.43 (dd, J = 15.4, 7.6 Hz, 4H), 7.38 (t, J = 7.4 Hz, 2H), 7.33 (t, J = 7.3 Hz, 1H), 5.36 (s, 2H).

*Benzyl 3-methylbenzoate (**2i**).*[27] Following the general procedure C, **2i** was isolated as a colorless oil. Yield: 140 mg, 62%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.88 (d, J = 9.0 Hz, 2H), 7.45 (d, J = 7.6 Hz, 2H), 7.41−7.28 (m, 5H), 5.36 (s, 2H), 2.39 (s, 3H).

*Benzyl 4-nitrobenzoate (**2j**).*[28] Following the general procedure C, **2j** was isolated as a light yellow solid. Yield: 185 mg, 72%; mp 81−82 °C (lit.[28] 82−83 °C); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.28 (d, J = 8.8 Hz, 2H), 8.24 (d, J = 8.8 Hz, 2H), 7.46 (d, J = 7.2 Hz, 2H), 7.43−7.37 (m, 3H), 5.41 (s, 2H).

*Methyl thiophene-2-carboxylate (**2k**).*[24] Following the general procedure C, **2k** was isolated as a light yellow oil. Yield: 89 mg, 63%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.81 (dd, J = 3.7, 1.0 Hz, 1H), 7.55 (dd, J = 5.0, 0.9 Hz, 1H), 7.10 (dd, J = 4.7, 3.9 Hz, 1H), 3.89 (s, 3H).

*Methyl cinnamate (**2l**).*[29] Following the general procedure C, **2l** was isolated as a light yellow oil. Yield: 137 mg, 85%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.70 (d, J = 16.0 Hz, 1H), 7.52 (dd, J = 6.4, 2.7 Hz, 2H), 7.42−7.35 (m, 3H), 6.44 (d, J = 16.0 Hz, 1H), 3.81 (s, 3H).

*4-Methoxybenzyl cinnamate (**2m**).*[30] Following the general procedure C, **2m** was isolated as a white solid. Yield: 163 mg, 61%; mp 57−58 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.71 (d, J = 16.0 Hz, 1H), 7.53−7.49 (m, 2H), 7.41−7.34 (m, 5H), 6.94−6.88 (m, 2H), 6.46 (d, J = 16.0 Hz, 1H), 5.19 (s, 2H), 3.82 (s, 3H).

*Methyl 2-(4-methoxyphenyl)acetate (**2n**).*[31] Following the general procedure C, **2n** was isolated as a light yellow oil. Yield: 95 mg, 53%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.19 (d, J = 8.6 Hz, 2H), 6.88−6.84 (m, 2H), 3.79 (s, 3H), 3.68 (s, 3H), 3.57 (s, 2H).

*Methyl 2-(4-nitrophenyl)acetate (**2o**).*[32] Following the general procedure C, **2o** was isolated as a light yellow solid. Yield: 140 mg, 72%; mp 48−49 °C (lit.[32] 46−48 °C); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.20 (d, J = 8.5 Hz, 2H), 7.46 (d, J = 8.4 Hz, 2H), 3.74 (s, 2H), 3.73 (s, 3H).

*Benzyl 2-(4-fluorophenyl)acetate (**2p**).*[33] Following the general procedure C, **2p** was isolated as a light yellow oil. Yield: 175 mg, 72%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.37−7.29 (m, 5H), 7.24 (dd, J = 8.3, 5.2 Hz, 2H), 7.00 (t, J = 8.7 Hz, 2H), 5.13 (s, 2H), 3.64 (s, 2H).

*3-Nitrobenzyl octanoate (**2q**).* Following the general procedure C, **2q** was isolated as a light yellow oil.Yield: 212 mg, 76%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.23 (s, 1H), 8.19 (d, J = 8.2 Hz, 1H), 7.68 (d, J = 7.6 Hz, 1H), 7.55 (t, J = 7.9 Hz, 1H), 5.20 (s, 2H), 2.39 (t, J = 7.5 Hz, 2H), 1.69−1.64 (m, 2H), 1.32−1.25 (m, 8H), 0.87 (t, J = 6.8 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.4, 148.4, 138.3, 133.8, 129.5, 123.1, 122.8, 64.6, 34.2, 31.6, 29.1, 28.9, 24.9, 22.6, 14.0; HRMS (ESI) m/z calcd for $C_{15}H_{21}NNaO_4^+$ [M + Na$^+$] 302.1363, found 302.1333.

*Benzyl 2-chloroacetate (**2r**).*[34] Following the general procedure C, **2r** was isolated as a colorless oil. Yield: 79 mg, 43%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.39−7.33 (m, 5H), 5.22 (s, 2H), 4.10 (s, 2H).

*tert-Butyl 3,4-dimethoxybenzoate (**2aa**).*[35] Following the general procedure C, **2aa** was isolated as a colorless oil. Yield: 200 mg, 84%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.62 (dd, J = 8.4, 1.8 Hz, 1H), 7.52 (d, J = 1.8 Hz, 1H), 6.86 (d, J = 8.4 Hz, 1H), 3.93 (d, J = 1.9 Hz, 6H), 1.59 (s, 9H).

*tert-Butyl 4-bromobenzoate (**2ab**).*[36] Following the general procedure C, **2ab** was isolated as a light yellow oil. Yield: 128 mg, 50%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.84 (d, J = 8.4 Hz, 2H), 7.55 (d, J = 8.4 Hz, 2H), 1.59 (s, 9H).

*tert-Butyl 2-(4-nitrophenyl)acetate (**2ac**).*[37] Following the general procedure C, **2ac** was isolated as a light yellow oil. Yield: 166 mg, 70%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.19 (d, J = 8.6 Hz, 2H), 7.45 (d, J = 8.5 Hz, 2H), 3.64 (s, 2H), 1.45 (s, 9H).

*Dodecyl benzoate (**2ad**).*[38] Following the general procedure C, **2ad** was isolated as a colorless oil. Yield: 261 mg, 90%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.05 (d, J = 7.9 Hz, 2H), 7.55 (t, J = 7.4 Hz, 1H), 7.44 (t, J = 7.7 Hz, 2H), 4.31 (t, J = 6.7 Hz, 2H), 1.81−1.72 (m, 2H), 1.48−1.23 (m, 18H), 0.88 (t, J = 7.0 Hz, 3H).

*Dodecyl 2-(4-nitrophenyl)acetate (**2ae**).* Following the general procedure C, **2ae** was isolated as a yellow solid. Yield: 261 mg, 75%; mp 46−47 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.19 (d, J = 8.4 Hz, 2H), 7.46 (d, J = 8.4 Hz, 2H), 4.11 (t, J = 6.7 Hz, 2H), 3.73 (s, 2H), 1.61 (dd, J = 13.5, 6.7 Hz, 2H), 1.27 (d, J = 16.1 Hz, 18H), 0.88 (t, J = 6.9 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.2, 147.2, 141.5, 130.3, 123.7, 65.6, 41.1, 31.9, 29.6, 29.6, 29.5, 29.3, 29.2, 28.5, 25.8, 22.7, 14.1; HRMS (ESI) m/z calcd for $C_{20}H_{31}NNaO_4^+$ [M + Na$^+$] 372.2145, found 372.2118.

*Methyl 2,4,6-trimethylbenzoate (**2af**).*[39] Following the general procedure C, **2af** was isolated as a colorless oil. Yield: 151 mg, 85%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 6.84 (s, 2H), 3.89 (s, 3H), 2.28 (d, J = 3.5 Hz, 9H).

*Methyl adamantan-1-carboxylate (**2ag**).*[40] Following the general procedure C, **2ag** was isolated as a colorless oil. Yield: 165 mg, 85%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.65 (s, 3H), 2.01 (s, 3H), 1.89 (d, J = 2.1 Hz, 6H), 1.71 (q, J = 12.2 Hz, 6H).

*tert-Butyl 2,4,6-trimethylbenzoate (**2ah**).*[41] Following the general procedure C, **2ah** was isolated as a colorless oil. Yield: 154 mg, 70%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 6.83 (s, 2H), 2.30 (d, J = 2.5 Hz, 6H), 2.26 (s, 3H), 1.59 (dd, J = 1.9, 1.3 Hz, 9H).

*Dodecyl 2,4,6-trimethylbenzoate (**2ai**).* Following the general procedure C, **2ai** was isolated as a colorless oil. Yield: 278 mg, 84%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 6.85 (s, 2H), 4.30 (t, J = 6.7 Hz, 2H), 2.28 (d, J = 8.1 Hz, 9H), 1.77−1.69 (m, 2H), 1.32−1.26 (m, 18H), 0.88 (t, J = 6.9 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.3, 139.1, 135.0, 131.3, 128.4, 65.0, 31.9, 29.7, 29.6, 29.5, 29.4, 29.3, 28.7, 26.1, 22.7, 21.1, 19.7, 14.1; HRMS (ESI) m/z calcd for $C_{22}H_{36}NaO_2^+$ [M + Na$^+$] 355.2608, found 355.2575.

*tert-Butyl adamantane-1-carboxylate (**2aj**).*[6] Following the general procedure C, **2aj** was isolated as a colorless oil. Yield: 99 mg, 42%; ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.99 (s, 3H), 1.83 (s, 6H), 1.69 (q, J = 12.4 Hz, 6H), 1.42 (d, J = 3.5 Hz, 9H).

IV. Formation of Dimer 3c and Its Thermal Decomposition. A solution of **1c** (1.0 mmol) and NBS (1.0 mmol) in toluene (10 mL) was stirred at room temperature for 1 h. Then EA (20 mL) was added, and the mixture was washed with saturated aqueous $Na_2S_2O_3$ (10 mL). The organic layer was dried over anhydrous Na_2SO_4, filtered, and removed under reduced pressure to give a white solid **3c** in quantitative yield: ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.55 (s, 8H), 3.87 (s, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 168.8, 131.6, 130.8, 130.2, 127.2, 63.6; HRMS (ESI) m/z calcd for $C_{16}H_{14}{}^{79}Br_2N_2NaO_4^+$ [M + Na$^+$] 478.9213, found 478.9200.

A solution of **3c** (1.0 mmol) in toluene (5 mL) was stirred at 80 °C for 1 h. Then the solvent was removed under reduced pressure. The residue was purified by flash column chromatography on silica gel to afford **2c** in 90% yield.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

^{1}H and ^{13}C NMR spectra data for all new compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

■ AUTHOR INFORMATION

Corresponding Author

*E-mail: duyunfeier@tju.edu.cn; kangzhao@tju.edu.cn.

Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

Y. Du acknowledges the National Natural Science Foundation of China (#21072148), Foundation (B) for Peiyang Scholar-Young Core Faculty of Tianjin University (2013XR-0144), and

the Innovation Foundation of Tianjin University (2013XJ-0005) for financial support.

REFERENCES

(1) For selected examples, see: (a) Petersen, T. B.; Khan, R.; Olofsson, B. *Org. Lett.* **2011**, *13*, 3454. (b) Twibanire, J. K.; Grindley, T. B. *Org. Lett.* **2011**, *13*, 2988. (c) Heller, S. T.; Sarpong, R. *Org. Lett.* **2010**, *12*, 4572. (d) Chakraborti, A. K.; Singh, B.; Chankeshwara, S. V.; Patel, A. R. *J. Org. Chem.* **2009**, *74*, 5967. (e) Sakakura, A.; Kawajiri, K.; Ohkubo, T.; Kosugi, Y.; Ishihara, K. *J. Am. Chem. Soc.* **2007**, *129*, 14775. (f) Bartoli, G.; Bosco, M.; Carlone, A.; Dalpozzo, R.; Marcantoni, E.; Melchiorre, P.; Sambri, L. *Synthesis* **2007**, 3489. (g) Huang, Z.; Reilly, J. R.; Buckle, R. N. *Synlett* **2007**, 1026. (h) Dhimitruka, I.; SantaLucia, J. *Org. Lett.* **2006**, *8*, 47. (i) Velusamy, S.; Borpuzari, S.; Punniyamurthy, T. *Tetrahedron* **2005**, *61*, 2011. (j) Srinivas, K. V. N. S.; Mahender, I.; Das, B. *Synthesis* **2003**, 2479. (k) Sharghi, H.; Hosseini Sarvari, M. *Tetrahedron* **2003**, *59*, 3627.

(2) Sutherland, I. O. In *Comprehensive Organic Chemistry*; Sutherland, I. O., Ed.;Pergamon Press: Oxford, 1979; p 871.

(3) Mulzer, J. In *Comprehensive Organic Synthesis*; Trost, B. M., Ed.; Pergamon Press: Oxford, 1991; p 323.

(4) Mulzer, J. In *Comprehensive Organic Functional Group Transformations*; Moody, C. J., Ed.; Pergamon: Oxford, 1995.

(5) For selected examples, see: (a) Xin, Z.; Gøgsig, T. M.; Lindhardt, A. T.; Skrydstrup, T. *Org. Lett.* **2012**, *14*, 284. (b) Alizadeh, M. H.; Kermani, T.; Tayebee, R. *Monatsh. Chem.* **2007**, *138*, 165. (c) Falck, J. R.; Sangrasa, B.; Capdevila, J. H. *Bioorg. Med. Chem.* **2007**, *15*, 1062. (d) Tararov, V. I.; Korostylev, A.; König, G.; Börner, A. *Synth. Commun.* **2006**, *36*, 187. (e) Salavati-Niasari, M.; Khosousi, T.; Hydarzadeh, S. *J. Mol. Catal. A: Chem.* **2005**, *235*, 150. (f) Singh, R.; Kissling, R. M.; Letellier, M. A.; Nolan, S. P. *J. Org. Chem.* **2004**, *69*, 209. (g) Grasa, G. A.; Singh, R.; Nolan, S. P. *Synthesis* **2004**, 971. (h) Liang, C. O.; Helms, B.; Hawker, C. J.; Frechet, J. M. J. *Chem. Commun.* **2003**, 2524. (i) Mukaiyama, T.; Shintou, T.; Fukumoto, K. *J. Am. Chem. Soc.* **2003**, *125*, 10538. (j) Kim, S.; Lee, J. I. *J. Org. Chem.* **1984**, *49*, 1712. (k) Masamune, S.; Hayase, Y.; Schilling, W.; Chan, W. K.; Bates, G. S. *J. Am. Chem. Soc.* **1977**, *99*, 6756. (l) Takimoto, S.; Inanaga, J.; Katsuki, T.; Yamagughi, M. *Bull. Chem. Soc. Jpn.* **1976**, *49*, 2335. (m) Rossi, R. A.; de Rossi, R. H. *J. Org. Chem.* **1974**, *39*, 855. (n) Kaiser, E. M.; Woodruff, R. A. *J. Org. Chem.* **1970**, *35*, 1198. (o) Parish, R. C.; Stock, L. M. *J. Org. Chem.* **1965**, *30*, 927.

(6) Glover, S. A.; Mo, G. *J. Chem. Soc., Perkin Trans. 2* **2002**, 1728.

(7) De Almeida, M. V.; Barton, D. H. R.; Bytheway, I.; Ferriera, J. A.; Hall, M. B.; Liu, W.; Taylor, D. K.; Thomson, L. *J. Am. Chem. Soc.* **1995**, *117*, 4870.

(8) Crawford, R. J.; Raap, R. *J. Org. Chem.* **1963**, *28*, 2419.

(9) Cooley, J. H.; Mosher, M. W.; Khan, M. A. *J. Am. Chem. Soc.* **1968**, *90*, 1867.

(10) Glover, S. A.; Mo, G.; Rauk, A. *Tetrahedron* **1999**, *5*, 3413.

(11) For selected examples of intermolecular electrophilic substitution reactions with nitrenium ions generated from *N*-halogen amides, see: (a) Shtamburg, V. G.; Gerasimenko, M. V.; Tsygankov, A. V.; Shishkin, O. V.; Zubatyuk, R. I.; Mazepa, A. V.; Kostyanovsky, R. G. *Mendeleev Commun.* **2011**, *21*, 50. (b) Kikugawa, Y.; Shimada, M.; Matsumoto, K. *Heterocycles* **1994**, *37*, 293. (c) Campbell, J. J.; Glover, S. A.; Rowbottom, C. A. *Tetrahedron Lett.* **1990**, *31*, 5377. (d) Kawase, M.; Kitamura, T.; Kikugawa, Y. *J. Org. Chem.* **1989**, *54*, 3394. (e) Glover, S. A.; Goosen, A.; McCleland, C. W.; Schoonraad, J. L. *Tetrahedron* **1987**, *43*, 2577. (f) Kikugawa, Y.; Kawase, M. *J. Am. Chem. Soc.* **1984**, *106*, 5728. (g) Glover, S. A.; Goosen, A.; McCleland, C. W.; Schoonraad, J. L. *J. Chem. Soc. Perkin Trans. 1* **1984**, 2255.

(12) (a) Shin, C.; Nanjo, K.; Yoshimura, J. *Tetrahedron Lett.* **1974**, *15*, 521. (b) Shin, C.; Nanjo, K.; Nishino, T.; Sato, Y.; Yoshimura, J. *Bull. Chem. Soc. Jpn.* **1975**, *48*, 2492.

(13) Wrigglesworth, J. W.; Cox, B.; Lloyd-Jones, J. C.; Booker-Milburn, K. I. *Org. Lett.* **2011**, *13*, 5326.

(14) Guimond, N.; Gouliaras, C.; Fagnou, K. *J. Am. Chem. Soc.* **2010**, *132*, 6908.

(15) Rakshit, S.; Grohmann, C.; Besset, T.; Glorius, F. *J. Am. Chem. Soc.* **2011**, *133*, 2350.

(16) Gissot, A.; Volonterio, A.; Zanda, M. J. *Org. Chem.* **2005**, *70*, 6925.

(17) Inamoto, K.; Kawasaki, J.; Hiroya, K.; Kondo, Y.; Doi, T. *Chem. Commun.* **2012**, *48*, 4332.

(18) Kawase, M.; Kitamura, T.; Kikugawa, Y. *J. Org. Chem.* **1989**, *54*, 3394.

(19) Koshti, N.; Naik, S.; Parab, B. *J. Indian Chem. Soc.* **2004**, *81*, 388.

(20) Jiang, H.; Lin, A.; Zhu, C.; Cheng, Y. *Chem. Commun.* **2013**, *49*, 819.

(21) Yamamoto, Y. *Adv. Synth. Catal.* **2010**, *352*, 478.

(22) Tschaen, B. A.; Schmink, J. R.; Molander, G. A. *Org. Lett.* **2013**, *15*, 500.

(23) Offermann, D. A.; Sejberg, J. J. P.; Mo, B.; Leatherbarrow, R. J.; Spivey, A. C.; McKendrick, J. E.; Holdom, M. D.; Beavil, A. J.; Sutton, B. J.; Helm, B. A. *J. Org. Chem.* **2012**, *77*, 3197.

(24) Ma, L.; Yuan, L.; Xu, C.; Li, G.; Tao, M.; Zhang, W. *Synthesis* **2013**, *45*, 45.

(25) Leduc, A. B.; Jamison, T. F. *Org. Process Res. Dev.* **2012**, *16*, 1082.

(26) Ishihara, K.; Niwa, M.; Kosugi, Y. *Org. Lett.* **2008**, *10*, 2187.

(27) Zhao, J.; Mueck-Lichtenfeld, C.; Studer, A. *Adv. Synth. Catal.* **2013**, *355*, 1098.

(28) Li, Y.; Deng, W.; Du, W. *Tetrahedron* **2012**, *68*, 3611.

(29) Schmidt, B.; Berger, R. *Adv. Synth. Catal.* **2013**, *355*, 463.

(30) Rolfe, A.; Loh, J. K.; Maity, P. K.; Hanson, P. R. *Org. Lett.* **2011**, *13*, 4.

(31) Feng, Y.; Wu, W.; Xu, Z.; Li, Y.; Xu, H.; Li, M. *Tetrahedron* **2012**, *68*, 2113.

(32) Duce, S.; Mateo, A.; Alonso, I.; Garcia Ruano, J. L.; Cid, M. B. *Chem. Commun.* **2012**, *48*, 5184.

(33) Roy, O.; Riahi, A.; Henin, F.; Muzart, J. *Eur. J. Org. Chem.* **2002**, *23*, 3986.

(34) Janczewski, D.; Synoradzki, L.; Wlostowski, M. *Synlett* **2003**, *3*, 420.

(35) Narasimhan, B.; Ohlan, S.; Ohlan, R.; Judge, V.; Narang, R. *Eur. J. Med. Chem.* **2009**, *44*, 689.

(36) Chang, C.; Chen, Y.; Hsu, C.; Chou, H.; Lin, J. T. *Org. Lett.* **2012**, *14*, 4726.

(37) Hu, M.; Li, L.; Wu, H.; Su, Y.; Yang, P.; Uttamchandani, M.; Xu, Q.; Yao, S. *J. Am. Chem. Soc.* **2011**, *133*, 12009.

(38) Liu, C.; Wang, J.; Meng, L.; Deng, Y.; Li, Y.; Lei, A. *Angew. Chem., Int. Ed.* **2011**, *50*, 5144.

(39) Shibuya, M.; Sato, T.; Tomizawa, M.; Iwabuchi, Y. *Chem. Commun.* **2009**, 1739.

(40) Bodnar, B. S.; Vogt, P. F. *J. Org. Chem.* **2009**, *74*, 2598.

(41) Zhao, H.; Pendri, A.; Greenwald, R. B. *J. Org. Chem.* **1998**, *63*, 7559.