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Microwave-Assisted Synthesis of 2-Aryl-2-oxazolines, 5,6-Dihydro-4*H*-1,3-oxazines, and 4,5,6,7-Tetrahydro-1,3-oxazepines

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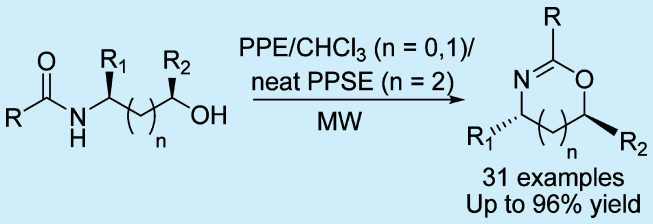
Supporting Information

ABSTRACT: The first general procedure for the synthesis of 5- to 7-membered cyclic iminoethers by microwave-assisted cyclization of ω-amido alcohols promoted by polyphosphoric acid (PPA) esters is presented. 2-Aryl-2-oxazolines and 5,6-dihydro-4*H*-1,3-oxazines were efficiently prepared using ethyl polyphosphate/$CHCl_3$. Trimethylsilyl polyphosphate in solvent-free conditions allowed for the synthesis of hitherto-unreported 4,5,6,7-tetrahydro-1,3-oxazepines. The method involves good to excellent yields and short reaction times.The reaction mechanism and the role of PPA esters were investigated in a chiral substrate.



2-Oxazolines are present in natural and synthetic products with biological activity as antibacterials,[1] antifungals,[2] antineoplastics,[3] deferrating agents,[4] antituberculosis agents,[5] insecticides,[6] and anti-inflammatories (deflazacort),[7] among others. In organic synthesis, 2-oxazolines represent valuable synthetic intermediates[8] and can act as protecting groups for carboxylic acids[9] and as masked aldehydes.[10] Some derivatives find application in the industrial preparation of pharmaceuticals such as cloramphenicol, thiamphenicol, and florphenicol.[11] On the other hand, chiral oxazolines and bisoxazolines are widely employed as ligands in asymmetric catalysis.[12] Other industrial applications of 2-oxazolines include resin and ink modifiers and polymer stabilizers.[13] Because of the importance of 2-oxazolines, an increasing number of methods have been developed for their synthesis.[14] Moreover, the presence of this heterocyclic core in many bioactive natural products and chiral catalysts has drawn considerable interest in the development of stereoselective methodologies.[15] One strategy for the synthesis of 2-oxazolines involves the reaction of amino alcohols with carboxylic acids or nitriles in the presence of activating agents or catalysts.[16,17] Alternatively, amino alcohols can react with aldehydes in oxidizing media yielding 2-oxazolines.[18] Miscelaneous methods include MCRs, metal-catalyzed reduction of oxazoles, and thionation followed by cyclodesulfurization.[19]

Another classical synthetic approach is ring closure of β-hydroxy amides. Several simple cyclization reagents have been used for this transformation: $SOCl_2$, PCl_5, and some transition-metal salts.[11a,20] This transformation can also be achieved using Ph_3P/DEAD,[21a,b] Ph_3P/DDQ,[21c,d] the Burgess reagent,[22] DAST,[23] and XtalFluor-E.[24] The main drawbacks of the reported procedures include long reaction times, drastic conditions, partial epimerization of α-stereocenters, chemical instability, and/or low functional group tolerance of the reagents.

5,6-Dihydro-4*H*-1,3-oxazines have been reported as useful synthons for selectively functionalized carboxylic acids, aldehydes, ketones,[25a,b] and polymers[25c] or in the preparation of natural products.[25d,e] This heterocyclic core is also present in more complex molecules acting as acetylcholinesterase and choline acetyl transferase inhibitors or antihypertensives.[26] The usual methods for their synthesis are an extension of those developed for 2-oxazolines.

In contrast to their five- and six-membered homologues, 4,5,6,7-tetrahydro-1,3-oxazepines have remained almost unexplored, probably due to the lack of suitable methods for their synthesis. Only one tetrahydro-1,3-oxazepine derivative has been described, which was obtained with modest yields by ring closure of the amido alcohol with XtalFluor-E (18 h, 55%)[23a] and by tritylation followed by cyclization with phosphonium anhydrides (>20 h, 31%).[27] According to a recent publication, such a compound shows activity as an inhibitor of glycogen phosphorylase a, a target enzyme in type II diabetes mellitus.[28]

In this context, novel and expeditious procedures combining easily available reagents, high yields, and general scope for 5- to 7-membered cyclic iminoethers are desired. Polyphosphoric acid (PPA) esters are mild, irreversible dehydrating agents of the Lewis acid type that activate oxygen and nitrogen functionalities toward nucleophilic attack and, at the same time, react chemically with water. Such reagents find application in a variety of reactions including heterocycle syntheses[29] and are compatible with the use of microwave irradiation.[30] To our knowledge, however, PPA esters had not been tested yet for the synthesis of cyclic iminoethers.

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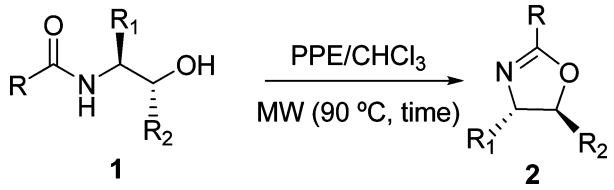
The required ω-amido alcohols were easily synthesized in high to quantitative yields by selective *N*-acylation of the corresponding amino alcohols with acyl chlorides.

We first examined the cyclization of *N*-benzoylaminoethanol **1a** with PPE/$CHCl_3$ (Table 1). The reaction, performed in an open-vessel microwave reactor under reflux (8 min at 70 °C), led to 2-phenyl-2-oxazoline in 88% yield. Using a closed-vessel reactor (3 min at 85 °C), compound **2a** was obtained in 95% yield. No reaction occurred in the absence of PPE, while classical Lewis acids ($ZnCl_2$, $AlCl_3$, BF_3) in stoichiometric amounts failed to promote the MW-assisted cyclization.[31]

Table 1. Synthesis of 2-Oxazolines 2



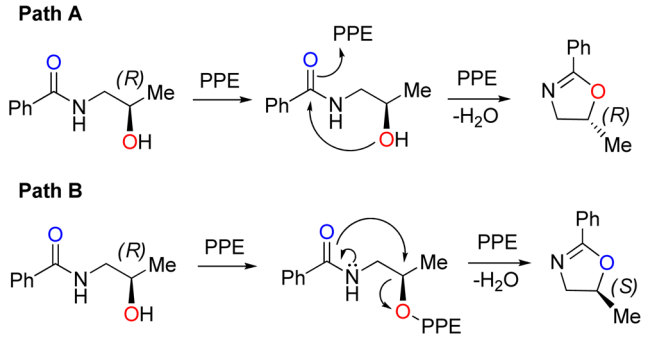
compd **2**	R	R_1	R_2	time (min)	yield[a] (%)
a	C_6H_5	H	H	8[b]	88
a	C_6H_5	H	H	3	95
b	4-$OCH_3C_6H_4$	H	H	3	96
c	4-$CH_3C_6H_4$	H	H	4	88
d	2-$CH_3C_6H_4$	H	H	4	90
e	4-ClC_6H_4	H	H	3	85
f	C_6H_5	CH_3	H	6	91
g	4-$OCH_3C_6H_4$	CH_3	H	6	90
h	C_6H_5	H	CH_3	4	88
i	4-ClC_6H_4	H	CH_3	2	85
j	4-$NO_2C_6H_4$	H	H	4	40[c]
k	2,4-$Cl_2C_6H_3$	H	H	4	10[c]
l	$C_6H_5CH_2$	H	H	8	traces

[a]Unless otherwise indicated, reactions were performed in a closed-vessel microwave reactor using a chloroformic solution of PPE (6 mL/mmol). [b]The reaction was performed in an open-vessel microwave reactor under reflux at 70 °C. [c]Decomposes during workup.

Under the optimized experimental conditions, several 2-oxazolines (**2a**–**e**) were synthesized in high to excellent yields in short reaction times (Table 1). The cyclization also led to satisfactory results for chiral substrates **2f**–**i**. The procedure was less efficient for derivatives with electron-withdrawing groups in the aryl moiety (**2j**,**k**) and for 2-benzyl-2-oxazoline **2l**, all of which underwent partial hydrolysis during the workup procedure. This is in line with previous literature reports, and is due to their relatively higher instability in acidic medium.[16b]

To gain further insight into the reaction mechanism and the role of PPA esters within it, we next examined the cyclization of the chiral amido alcohol **1h** (Scheme 1). On the basis of previous literature data, two mechanisms are possible for the cyclization: nucleophilic attack of the alcohol to the PPE/PPSE-activated amide carbonyl followed by dehydration (Scheme 1, path A) or OH activation followed by intramolecular S_N2-like substitution (Scheme 1, path B). Cyclization of (*R*)-*N*-benzoyl-1-amino-2-propanol **1h** with PPE/MW led exclusively to (*S*)-4-methyl-2-phenyloxazoline **2h**. Analogous results were obtained with neat PPSE/MW. This stereochemical outcome supports an S_N2-like mechanism (Scheme 1, path B) for the reaction and suggests that PPA esters activate the OH group, making it a better nucleofuge.

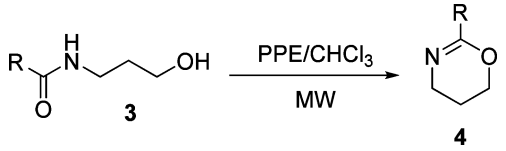
Scheme 1. Alternative Reaction Paths for the PPE/MW[a] Cyclization of 1h



[a]MW irradiation: 4 min at 90 °C.

In order to widen the scope of the method, we next examined the applicability of the PPE/MW system to the synthesis of 5,6-dihydro-4*H*-1,3-oxazines. As shown in Table 2, trimethylenic amido alcohols **3a**–**j** were smoothly converted to the corresponding cyclic imidates **4a**–**g** in high yields, including 4-nitro derivative **4f**. *Ortho*-substituted derivatives **4h**,**i** as well as 2-benzyldihydrooxazine **4j** gave comparatively lower yields.

Table 2. Synthesis of 5,6-Dihydro-4*H*-1,3-oxazines 4



compd **4**	R	reaction conditions[a]	yield (%)
a	C_6H_5	5 min, 70 °C	85
b	4-$OCH_3C_6H_4$	5 min, 70 °C	96
c	4-$CH_3C_6H_4$	5 min, 90 °C	84
d	2-$CH_3C_6H_4$	5 min, 90 °C	92
e	4-ClC_6H_4	5 min, 70 °C	91
f	4-$NO_2C_6H_4$	5 min, 70 °C	85
g	2-$NO_2C_6H_4$	5 min, 90 °C	78
h	2-FC_6H_4	3 min, 90 °C	65
i	2,4-$Cl_2C_6H_3$	3 min, 90 °C	27[b]
j	$C_6H_5CH_2$	10 min, 90 °C	35[b]

[a]Reactions were performed in a closed vessel microwave reactor using a chloroformic solution of PPE (6 mL/mmol). [b]Decomposes during workup.

In view of these encouraging results, we decided to examine the performance of the PPE/MW system in the cyclization reaction leading to the more challenging 7-membered cyclic iminoethers. As previously mentioned, the literature shows only one example of such a heterocyclic system. Ring-closure reactions leading to medium-sized rings usually require comparatively longer reaction times and/or harsher conditions than their five- and six-membered homologues. This is usually attributed to the lower probability of both reacting sites to interact as the length of the alkylene chain increases and to unfavorable enthalpic and entropic factors.[32] In fact, the attempted cyclization of *N*-benzoyl-4-aminobutanol (**5a**) with PPE/$CHCl_3$ under microwave irradiation (reflux, 5 min at 90 °C) was not successful (Table 3).

Previous results showed that PPSE promotes the cyclization of some substrates which are unreactive toward PPE.[30b,33] This

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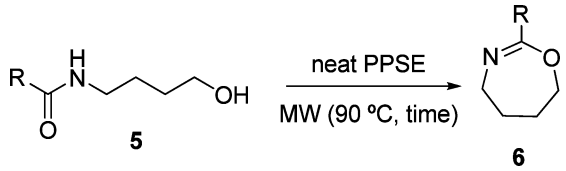
Table 3. Synthesis of 4,5,6,7-Tetrahydro-1,3-oxazepines 6



compd 6	R	reaction conditions[a]	yield (%)
a	C_6H_5	PPE/$CHCl_3$, 5 min[b]	*c*
a	C_6H_5	PPSE/CH_2Cl_2, 5 min[b]	20[c]
a	C_6H_5	10 min, conventional heating	30[c]
a	C_6H_5	5 min	80
b	4-$OCH_3C_6H_4$	8 min	73
c	4-$CH_3C_6H_4$	5 min	71
d	2-$CH_3C_6H_4$	5 min	60
e	4-ClC_6H_4	5 min	77
f	4-$NO_2C_6H_4$	6 min	76
g	2-FC_6H_4	5 min	71
h	2,4-$Cl_2C_6H_3$	6 min	67
i	$C_6H_5CH_2$	5 min	61

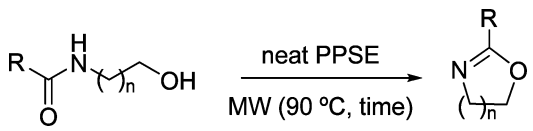
[a]Unless otherwise indicated, reactions were performed in solvent-free conditions in an open-vessel microwave reactor using neat PPSE (6 g/mmol). [b]The reaction was performed under reflux in an open-vessel microwave reactor. [c]Decomposes during workup.

prompted us to investigate the use of PPSE for the synthesis of the tetrahydrooxazepine under different experimental conditions (Table 3). The reaction of **5a** with PPSE/CH_2Cl_2 (5 min at 90 °C) led to low conversion of the precursor. A slightly better yield was obtained by working under solvent-free conditions under conventional heating (10 min at 90 °C), although decomposition products were observed. Finally, complete disappearance of the substrate was attained by working under solvent-free conditions under MW irradiation (5 min at 90 °C), yielding 80% of compound **6a** after purification.

Using the optimized reaction conditions, we synthesized a series of novel tetrahydro-1,3-oxazepines **6b–i** (Table 3). The method led to the desired seven-membered cyclic imidates with good to high yields in remarkably short reaction times and compares favorably with the previously reported examples.[23a,27] At variance with the lower homologues (Tables 1, 2), 2-*ortho*-substituted aryl or 2-benzyl derivatives were easily synthesized and gave only slightly lower yields (Table 3).

Taking into account the previous results, and in order to improve the yields of derivatives **2j–l** and **4i,j**, their synthesis was attempted with PPSE under solvent-free conditions under microwave irradiation (Table 4). This modification led in general to remarkable improvements in the yields.

Table 4. Improved Synthesis of Compounds 2j–l and 4f,j



compd	R	*n*	time (min)	yield (%)
2j	4-$NO_2C_6H_4$	1	5	51
2k	2,4-$Cl_2C_6H_3$	1	5	31
2l	$CH_2C_6H_5$	1	3	50
4i	2,4-$Cl_2C_6H_3$	2	3	56
4j	$C_6H_5CH_2$	2	10	55

In conclusion, we have developed a novel and efficient protocol for the synthesis of 2-aryl-2-oxazolines and their six- and seven-membered homologues from amido alcohols. To our knowledge, this is the first general method for the construction of the 4,5,6,7-tetrahydro-1,3-oxazepine core reported in the literature. The ring-closure reactions were conducted under microwave irradiation and promoted by PPA esters in the absence of metals, catalysts, or additives. Notably, classical Lewis acids failed to promote this transformation.The method involves inexpensive and easily available precursors and reagents and leads to high yields of the heterocycles in short reaction times together with controlled stereochemistry in the case of chiral substrates.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.orglett.6b03122.

Experimental procedures, characterization of new compounds, and ^1H and ^{13}C NMR spectra (PDF)

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Notes

The authors declare no competing financial interest.

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■ REFERENCES

(1) Kline, T.; Andersen, N. H.; Harwood, E. A.; Bowman, J.; Malanda, A.; Endsley, S.; Erwin, A. L.; Doyle, M.; Fong, S.; Harris, A. L.; Mendelsohn, B.; Mdluli, K.; Raetz, C. R. H.; Stover, C. K.; Witte, P. R.; Yabannavar, A.; Zhu, S. *J. Med. Chem.* **2002**, *45*, 3112.

(2) Bode, B. H.; Irschik, H.; Wenzel, S. C.; Reichenbach, H.; Müller, R.; Höfle, G. *J. Nat. Prod.* **2003**, *66*, 1203.

(3) (a) Prinsep, M. R.; Moore, R. E.; Levine, I. A.; Patterson, G. M. L. *J. Nat. Prod.* **1992**, *55*, 140. (b) Kim, M. Y.; Vankayalapati, H.; Shin-ya, K.; Wierzba, K.; Hurley, L. H. J. *J. Am. Chem. Soc.* **2002**, *124*, 2098.

(4) Bergeron, R. J.; Xin, M. G.; Weimar, W. R.; Smith, R. E.; Wiegand, J. *J. Med. Chem.* **2001**, *44*, 2469.

(5) Moraski, G. C.; Chang, M.; Villegas-Estrada, A.; Franzblau, S. G.; Möllmann, U.; Miller, M. J. *Eur. J. Med. Chem.* **2010**, *45*, 1703.

(6) Miyamoto, S.; Suzuki, J.; Kikuchi, Y.; Toda, K.; Itoh, Y.; Ikeda, T.; Ishida, T.; Hariya, Y.; Tsukidate, Y.; Morikawa, C. European Patent 0432661A2, 1991.

(7) Markham, A.; Bryson, H. M. *Drugs* **1995**, *50*, 317.

(8) (a) McGarvey, G. J.; Wilson, K. J.; Shanholtz, C. E. *Tetrahedron Lett.* **1992**, *33*, 2641. (b) Padwa, A.; Rasmussen, J. K.; Tremper, A. *J. Am. Chem. Soc.* **1976**, *98*, 2605. (c) O'Malley, S.; Kodadek, T. *J. Am. Chem. Soc.* **1989**, *111*, 9116.

DOI: 10.1021/acs.orglett.6b03122
Org. Lett. 2016, 18, 6116–6119

(9) (a) Gabriel, S. *Liebigs Ann. Chem.* **1915**, *409*, 305. (b) Meyers, A. I.; Smith, E. M.; Jurjevich, A. F. *J. Am. Chem. Soc.* **1971**, *93*, 2314. (c) Gaumont, A. C.; Gulea, M.; Levillain, J. *Chem. Rev.* **2009**, *109*, 1371.
(10) Meyers, A. I.; Nabeya, A.; Adickes, H. W.; Politzer, I. R.; Malone, G. R.; Kovelesky, A. C.; Nolen, R. L.; Portnoy, R. C. *J. Org. Chem.* **1973**, *38*, 36.
(11) (a) Wu, G.-Z.; Tormos, W. I. World Patent 94/14764, 1994. (b) Towson, J. C. World Patent 150406A1, 2008. (c) Franchino, A.; Jakubec, P.; Dixon, D. J. *Org. Biomol. Chem.* **2016**, *14*, 93.
(12) McManus, H. A.; Guiry, P. J. *Chem. Rev.* **2004**, *104*, 4151.
(13) (a) Miranda, T. J.; Herman, H. R. US Patent 3438943, 1969. (b) Clark, E. L. US Patent 3367895, 1968. (c) Carlini, R.; Sacripante, G. G.; Drappel, S. V.; Allen, C. G. US Patent 8500260B2, 2013.
(14) Bansal, S.; Halve, A. K. *Int. J. Pharm. Sci. Res.* **2014**, *5*, 4601.
(15) (a) Brandstätter, M.; Roth, F.; Luedtke, N. W. *J. Org. Chem.* **2015**, *80*, 40. (b) Parsons, R. L.; Heathcock, C. H. *J. Org. Chem.* **1994**, *59*, 4733.
(16) (a) Vorbrüggen, H.; Krolikiewicz, K. *Tetrahedron Lett.* **1981**, *22*, 4471. (b) Cwik, A.; Hell, Z.; Hegedüs, A.; Finta, Z.; Horváth, Z. *Tetrahedron Lett.* **2002**, *43*, 3985.
(17) (a) Bazgir, A.; Amini, M. M.; Fazaeli, Y. *Open Catal. J.* **2010**, *2*, 163. (b) Moghadam, M.; Mirkhani, V.; Tangestaninejad, S.; Mohammadpoor-Baltork, I.; Kargar, H. *J. Iran. Chem. Soc.* **2009**, *6*, 251. (c) Mohammadpoor-Baltork, I.; Moghadam, M.; Tangestaninejad, S.; Mirkhani, V.; Eskandari, Z. *Ultrason. Sonochem.* **2010**, *17*, 857.
(18) (a) Schwekendiek, K.; Glorius, F. *Synthesis* **2006**, *2006*, 2996. (b) Ishihara, M.; Togo, H. *Tetrahedron* **2007**, *63*, 1474. (c) Karade, N. N.; Tiwari, G. B.; Gampawar, S. V. *Synlett* **2007**, *2007*, 1921.
(19) (a) Boissarie, P. J.; Hamilton, Z. E.; Lang, S.; Murphy, J. A.; Suckling, C. J. *Org. Lett.* **2011**, *13*, 6256. (b) Kuwano, R.; Kameyama, N.; Ikeda, R. *J. Am. Chem. Soc.* **2011**, *133*, 7312. (c) Goud, D. R.; Pathak, U. *Synthesis* **2012**, *44*, 3678.
(20) Rock, K.; Smith, G. European Patent 0164219B1, 1989.
(21) (a) Roush, D. M.; Patel, M. M. *Synth. Commun.* **1985**, *15*, 675. (b) Galéotti, N.; Montagne, C.; Poncet, J.; Jouin, P. *Tetrahedron Lett.* **1992**, *33*, 2807. (c) Ishihara, M.; Togo, H. *Tetrahedron* **2007**, *63*, 1474. (d) Iranpoor, N.; Firouzabadi, N.; Akhlaghinia, B.; Nowrouzi, N. *J. Org. Chem.* **2004**, *69*, 2562 and references cited therein.
(22) (a) Wipf, P.; Fritch, P. C. *J. Am. Chem. Soc.* **1996**, *118*, 12358. and references cited therein (b) Liyanage, W.; Weerasinghe, L.; Strong, R. K.; Del Valle, J. R. *J. Org. Chem.* **2008**, *73*, 7420. (c) Doi, T.; Yoshida, M.; Shin-ya, K.; Takahashi, T. *Org. Lett.* **2006**, *8*, 4165. (d) Plant, A.; Stieber, F.; Scherkenbeck, J.; Losel, P.; Dyker, H. *Org. Lett.* **2001**, *3*, 3427. (e) Castellano, S.; Kuck, D.; Sala, M.; Novellino, E.; Lyko, F.; Sbardella, G. *J. Med. Chem.* **2008**, *51*, 2321. (f) Ying, Y.; Hong, J. *Tetrahedron Lett.* **2007**, *48*, 8104.
(23) (a) Pouliot, M.; Angers, L.; Hamel, J.; Paquin, J. *Tetrahedron Lett.* **2012**, *53*, 4121. (b) Phillips, A. J.; Uto, Y.; Wipf, P.; Reno, M. J.; Williams, D. R. *Org. Lett.* **2000**, *2*, 1165. (c) Lellouche, J.-P.; Lafargue, P.; Guenot, P. *Heterocycles* **1995**, *41*, 947 and references cited therein.
(24) Pouliot, M.; Angers, L.; Hamel, J.; Paquin, J. *Tetrahedron Lett.* **2012**, *53*, 4121.
(25) (a) Schmidt, R. R. *Synthesis* **1972**, *1972*, 333. (b) Joo, J.-E.; Lee, K.-Y; Pham, V.-T.; Tian, Y.-S.; Ham, W.-H. *Org. Lett.* **2007**, *9*, 3627. (c) Hu, L.; Frech, R.; Glatzhofer, D. T.; Mason, R.; York, S. S. *Solid State Ionics* **2008**, *179*, 401. (d) Moriwake, T.; Saito, S.; Tamai, H.; Mitsuda, H.; Inaba, M. *Heterocycles* **1985**, *23*, 277. (e) Joo, J.-E.; Lee, K.-Y; Pham, V.-T.; Tian, Y.-S.; Ham, W.-H. *Org. Lett.* **2007**, *9*, 3627.
(26) Among others: (a) Sauvaitre, T.; Barlier, M.; Herlem, D.; Gresh, N.; Chiaroni, A.; Guenard, D.; Guillou, C. *J. Med. Chem.* **2007**, *50*, 5311. (b) Mehta, N. B.; Musso, D. L.; White, H. L. *Eur. J. Med. Chem.* **1985**, *20*, 443. (c) Hewitt, M.; Schneider, T. R.; Szemeredi, Z.; Hajnal, A.; Wolfling, J.; Schneider, G. *Acta Crystallogr., Sect. C: Cryst. Struct. Commun.* **2000**, *56*, 363.
(27) Petersson, M. J.; Jenkins, I. D.; Loughlin, W. A. *Org. Biomol. Chem.* **2009**, *7*, 739.
(28) Schweiker, S. S.; Loughlin, W. A.; Lohning, A. S.; Petersson, M. J.; Jenkins, I. D. *Eur. J. Med. Chem.* **2014**, *84*, 584.
(29) López, S. E.; Restrepo, J.; Salazar, J. *J. Chem. Res.* **2007**, *2007*, 497.
(30) (a) Díaz, J. E.; Bisceglia, J. A.; Mollo, M. C.; Orelli, L. R. *Tetrahedron Lett.* **2011**, *52*, 1895. (b) Díaz, J. E.; Gruber, N.; Orelli, L. R. *Tetrahedron Lett.* **2011**, *52*, 6443.
(31) A possible explanation of this behavior is that these reagents do not behave as dehydrating agents.
(32) Sharma, A.; Appukkuttan, P.; Van der Eycken, E. *Chem. Commun.* **2012**, *48*, 1623.
(33) Li, W.; Fuchs, P. L. *Org. Lett.* **2003**, *5*, 4061.

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