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LiO*t*Bu Promoted 5-*Exo*-dig Cyclization of Propargyl Alcohols and Isocyanates for the Synthesis of Multisubstituted 3*H*-Oxazol-2-ones and Oxazolidin-2-ones

S. Antony Savarimuthu,*[a] S. Augustine Thomas,[a] D.G. Leo Prakash[b] and Thirumanavelan Gandhi[c]

Abstract: This study presents an efficient procedure for synthesis of 3,4,5-trisubstituted 3*H*-oxazol-2-ones and 3,4-disubstituted (Z)-oxazolidin-2-ones from substituted propargyl alcohols and aryl/alkyl isocyanates in the presence of LiO*t*Bu, a base, and DMF, a solvent. This one-step, low-cost and gram scale synthesis exhibits superior atom economy, good to excellent yields, enhanced substrate scope and, high functional group tolerance and uses column chromatography-free purifications. Further, a product containing bromo substituent was successfully examined for Suzuki coupling with a view to amplifying the complexity of the molecule. Finally, the three component (aniline, Di-tert-butyldicarbonate and propargyl alcohol) reaction was demonstrated to get the oxazolon-2-ones (3*H*-oxazol-2-one and oxazolidin-2-one).

Introduction

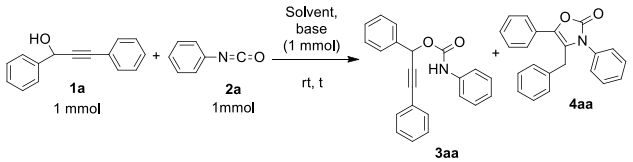
Oxazolones are one of the significant structural motifs exemplified in both natural and non-natural products, and exhibits wide range of biological activities.[1] These heterocycles used as building blocks for various organic reactions,[2] especially by cycloaddition reactions in the area of natural product synthesis. Specifically, multi-substituted oxazolones such as 3*H*-oxazol-2-ones and oxazolidin-2-ones displays superior pharmaceutical properties such as excellent cardiotonic activity,[3] model compound for ring oxidation catalysed by aldehyde oxidase[4] and cyclooxygenase-2-inhibitors.[5] However, most of current synthetic procedures suffer from certain drawbacks such as toxic transition metal catalysts,[6] corrosive reagents,[5b,7] multistep reaction[1a,8] and harsh reaction conditions.[9] Owing to the above limitations, development of a simple and efficient methodology to synthesize 3*H*-oxazol-2-ones and oxazolidin-2-ones are highly desirable. Utilization of propargyl alcohols as a valuable intermediates are frequent in the synthesis of complex natural product with significant biological activity.[10]

Propargyl alcohols have been used in synthesis of heterocyclic compounds due to their concrete electrophilic[11] as well as nucleophilic[12] nature. For instance, silver catalyzed[13] incorporation of tertiary propargyl alcohols with pressurized gaseous carbon dioxide (electrophile) produced [1,3]dioxolan-2-ones. Compared to carbon dioxide, isocyanates[14] are very reactive and more effective electrophiles towards water, alcohols and amines and can also take part in Diels-Alder reactions. In the literature are found many heterocyclic syntheses, either from terminal primary propargyl alcohols[15] or tertiary propargyl alcohols;[16] however, their synthesis using internal secondary and primary propargyl alcohols is limited. Hence, it is proposed to synthesize heterocyclic compounds by the cross-coupling of internal propargyl alcohols with isocyanates through 5-*exo*-dig cyclization. This approach discloses a straightforward synthesis of 3,4,5-trisubstituted 3*H*-oxazol-2-ones and 3,4-disubstituted (Z)-oxazolidin-2-ones from either internal secondary or primary propargyl alcohols with LiO*t*Bu as base and in DMF as solvent, and involves mostly simple room temperature reactions and superior atom economy.

Results and Discussion

As regards synthesis of multisubstituted 3*H*-oxazol-2-ones from propargyl alcohols, the method of arriving at the optimum reaction conditions is sketched in Table 1. The numerals 1, 2, 3 and 4 in Table 1 denote propargyl alcohols, isocyanates, non-cyclized product and 3,4,5-trisubstituted 3*H*-oxazol-2-ones respectively.

Table 1. Study of optimum reaction conditions[a]



Entry	Solvent	Base	t (h)	**3aa** Yield (%)[a]	**4aa** Yield (%)[a]
1	CH_2Cl_2	DBU	20	65	8
2	CH_2Cl_2	DBN	20	68	14
3	THF	DBN	20	55	8
4	Dioxane	DBN	20	45	14
5	DMF	DBN	1	0	0
6	ACN	DBN	10	15	68
7	DME	DBN	10	52	10
8	CH_2Cl_2	DABCO	20	15	0
9	DMF	Na_2CO_3	1	0	0
10	DMF	K_2CO_3	1	20	0
11	THF	Cs_2CO_3	1	30	0
12	DMF	Cs_2CO_3	1	70	0
13	DMF	LiOH	20	35	45
14	DMF	NaOH	20	30	40
15	DMF	KOH	20	20	21
16	DMF	$NaOCH_3$	15	0	0
17	DMF	NaOEt	15	25	0
18	DMF	NaO*t*Bu	1	45	0
19	DMF	KO*t*Bu	1	40	32
20	THF	LiO*t*Bu	15	49	27
21	DME	LiO*t*Bu	5	41	38

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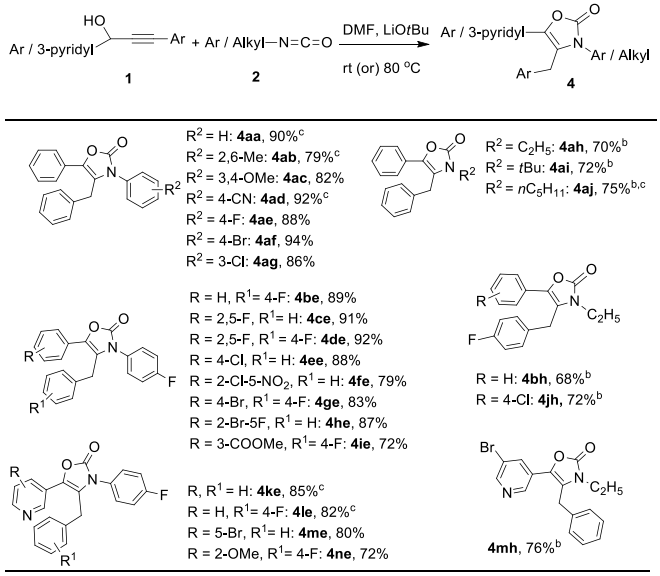
22	DMAc	LiO*t*Bu	1	0	72
23	**DMF**	**LiO*t*Bu**	**1**	**0**	**90**

[a] Yields of isolated products. THF = tetrahydrofuran, DME = dimethyl ether, DMF = N,N-dimethyl-formamide, DMAc = N, N-dimethyl-acetamide, DBU = 1,8-diazabicyclo[5.4.0]undec-7-ene, DBN = 1,5-diazabicyclo[4.3.0]non-5-ene, DABCO = 1,4-diazabicyclo[2.2.2]octane, Et = ethyl, *t*Bu = tertiary butyl, ACN = acetonitrile, rt = room temperature, t = time, h = hour, N_2 = nitrogen.

The reactions summarized in Table 1 carried out with phenyl isocyanate (**2a**) and 1,3-diphenyl-prop-2-yn-1-ol (**1a**) with organic bases (entries 1-8) indicate that only the reaction conditions shown in entry 6 led to 68% of 4-benzyl-3,5-diphenyl-3*H*-oxazol-2-one (**4aa**). Reactions (entries 9-12) with inorganic carbonate bases yielded no heterocyclic product while those with inorganic hydroxide bases (entries 13-15) gave only 20-45% of **4aa**. The results of attempts with metal alkoxide bases in specified solvents are presented in entries 16-23 and it is evident that use of LiO*t*Bu as the base and DMF as the solvent points (entry 23) to the optimum reaction conditions with the exceptional yield i.e., 90% of **4aa**. Subsequently, the scope of the reaction was examined on **1a** with ten isocyanates (seven aromatic and three alkyl) (Table 2) by employing the optimum reaction conditions and the yields of the isolated products are presented also.

Table 2. Synthesis of twenty five 3,4,5-trisubstituted 3*H*-oxazol-2-ones[a]



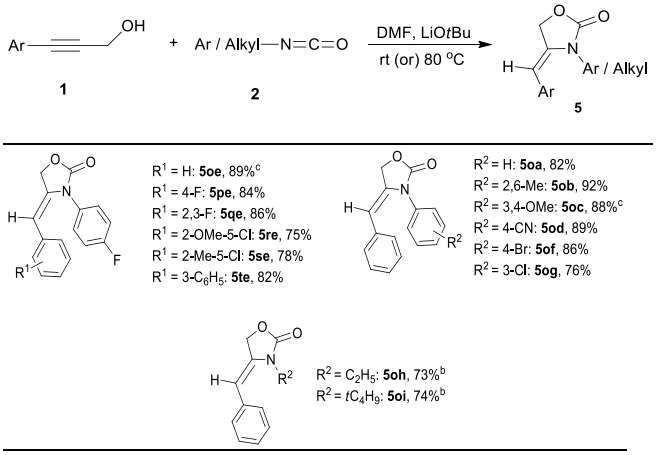
[a] Reaction conditions: **1** (4.8058 mmol), **2** (4.8058 mmol), LiO*t*Bu (4.8058 mmol) in 10 volume of DMF wrt **1** under N_2 atmosphere. [b] Reactions were carried out at 80 °C. [c] Reactions were carried out on gram scale.

The results confirm that both the electron rich aromatic isocyanates and the electron deficient aromatic isocyanates carrying cyano, fluoro,[17] bromo or chloro substituents, afforded fairly good yields of the respective products (**4aa**-**4ag**). At room temperature three aliphatic isocyanates used yielded no heterocyclic product[18] and when the reaction mixtures were kept at 80 °C, the corresponding heterocyclic products **4ah**-**4aj** were produced in good yields.

The scope was extended to different substituted propargyl alcohols with 1-fluoro-4-isocyanatobenzene; the mono-, di- or tri-fluoro substituted phenyl propargyl alcohol separately incorporated with 1-fluoro-4-isocyanatobenzene ended with excellent yields (>89%) of desired product (**4be**-**4de**). The reactions were also productive (**4ee**-**4fe**) with chloro or chloro, nitro phenyl substituted propargyl alcohols. In addition, bromo and fluoro substituted phenyl propargyl alcohols, irrespective of the positions of substituents, offered white crystalline 3*H*-oxazol-2-ones (**4ge**-**4he**) and the meta- substituted aromatic propargyl alcohol with 1-fluoro-4-isocyanatobenzene yielded 72% of **4ie**. The two reactions carried out by using isocyanatoethane at 80 °C afforded good yields of **4bh** and **4jh**. The additional examination of this transformation with 3-pyridyl attached propargyl alcohols offered 85% of **4ke** and 82% of **4le**. The electron-withdrawing -Br or electron-donating -OMe substituents attached to the pyridyl propargyl alcohol were found to react with aromatic and aliphatic isocyanates affording the desired products (**4me**, **4ne** and **4mh**) in very good yields.

DMF (solvent) and LiO*t*Bu (base) used above were employed with the internal primary propargyl alcohols going for 5-*exo*-dig cyclization without double bond migration resulted oxazolidin-2-ones[19] with highly Z selective and the yields of the isolated products are indicated in Table 3. In the first part of the investigation, the reactivity of 1-fluoro-4-isocyanatobenzene was tested separately with six different internal primary propargyl alcohols.

Table 3. Synthesis of fourteen 3,4-disubstituted oxazolidin-2-ones[a]



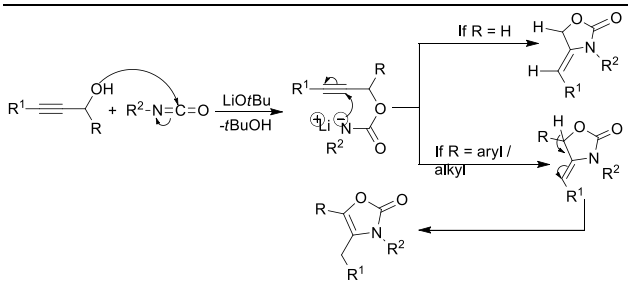
[a] Reaction conditions: **1** (6.9680 mmol), **2** (6.9680 mmol), LiO*t*Bu (6.9680 mmol) in 10 volume of DMF wrt **1** under N_2 atmosphere. [b] Reactions were carried out at 80 °C. [c] Reactions were carried out on gram scale.

For example, when use was made of the unsubstituted 4-fluoro or 2,3-difluoro substituted phenyl propargyl alcohols, the reaction proceeded smoothly to afford the corresponding products in vey good to excellent yields (**5oe**-**5qe**). Moreover, with R^1 as 2-OMe and 5-Cl or 2-Me and 5-Cl or 3-Ph products were **5re** -**5te**. It is noticed that all the six aromatic internal propargyl alcohols irrespective of the electron rich or electron deficient nature of substituent(s) provided fairly good yields of the desired products.

To further evaluate the flexibility of this synthetic procedure, 3-phenyl propargyl alcohol was reacted separately with six aromatic and two aliphatic isocyanates. The three electron-rich aromatic isocyanates afforded 82% of **5oa**, 92% of **5ob** and 88% of **5oc**,[20] while aromatic isocyanates carrying the electron withdrawing substituents namely 4-CN, 4-Br and 3-Cl respectively gave products **5od**, **5of** and **5og** in good yields. Finally, the two aliphatic isocyanates served as good reactants to afford the

desired oxazolidin-2-ones **5oh-5oi** in fairly good yields. Based on the above experiments, the possible reaction mechanism embracing coupling and cyclization reaction is proposed in Scheme 1.

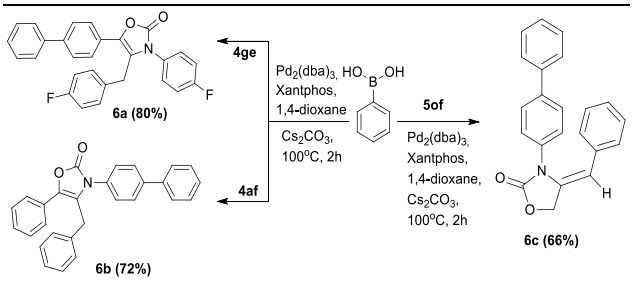
Scheme 1. Possible reaction mechanism.



Initially LiO*t*Bu deprotonates the OH of a propargyl alcohol and the resulting anion couples with the carbon of the isocyanate group; subsequently the nitrogen anion of the isocyanate cyclizes (via 5-*exo*-dig) with the carbon-2 of the alcohol part and the newly generated carbanion is protonated forming oxazolidin-2-ones. In the case of a secondary propargyl alcohol, the exocyclic double bond is rearranged to give 3*H*-oxazol-2-ones.

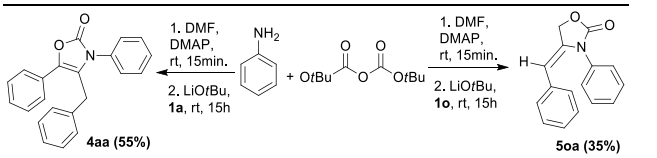
In addition, Suzuki coupling reaction has been tested on oxazolon-2-ones carrying Br (Scheme 2).

Scheme 2. Suzuki coupling of bromo substituted oxazolon-2-ones with phenyl boronicacid. Reaction conditions: **4** (or) **5** (0.4534 mmol), phenyl boronicacid (0.5441 mmol), Cs_2CO_3 (0.9068 mmol), $Pd_2(dba)_3$ (5 mol%), Xantphos (10 mol%) in 10 volume of 1,4-dioxane wrt **4** or **5** under N_2 atmosphere at 100 °C for 2 h; isolated yield was reported.



Suzuki coupling of bromo compounds **4ge**, **4af** and **5of** with phenyl boronic acid with $Pd_2(dba)_3$, Xantphos, Cs_2CO_3 in 1,4-dioxane afforded moderate yields of **6a**, **6b** and **6c**, respectively (Scheme 2). Impressed by the synthesis by Knolker et al. of isocyanates[21] from aniline and Boc anhydride with DMAP base an extension of this approach was conceived to prepare oxazolon-2-ones. As presented in Scheme 3 a solution of Boc anhydride, DMAP, and aniline in DMF at room temperature were stirred for 15 minutes. To this, LiO*t*Bu and propargyl alcohol **1a** (or **1o**) were added and the mixture was stirred at room temperature for 15 h to get the corresponding oxazolon-2-one.

Scheme 3. Extension reaction for making 4aa and 5oa[a]



[a] Reaction conditions: di-tert-butyldicarbonate (Boc anhydride) (2.5789), 4-dimethylaminopyridine (DMAP) (2.5789), aniline (2.1491 mmol) in DMF under N_2 atmosphere at room temperature for 15 min. and then were added LiO*t*Bu (2.1491 mmol) and propargyl alcohol (1.7193 mmol) at room temperature for 15 h; isolated yield was reported.

Conclusions

The new and efficient synthetic procedures have been found for making different 3*H*-oxazol-2-ones and oxazolidin-2-ones. Reactions of equimolar quantities of secondary propargyl alcohol, isocyanate and LiO*t*Bu lead to 5-*exo*-dig cyclization and double bond migration producing good to excellent yields of 3,4,5-trisubstituted 3*H*-oxazol-2-ones. A similar synthetic procedure in the case of primary propargyl alcohols produces 3,4-disubstituted oxazolidin-2-ones with highly Z isomer selective without double bond migration. These synthetic procedures put forth many advantages, irrespective of the electron-withdrawing or electron-donating substituents in the propargyl alcohols or isocyanates, such as quick reaction time, mostly simple room temperature reactions, high functional group tolerance, scalability and significant yield. Suzuki arylation of the bromo substituted oxazol-2-ones, as well as the oxazolidin-2-one was also carried out and moreover an extension reaction was demonstrated for synthesizing oxazolon-2-one.

Supporting Information

Detailed experimental procedures and spectroscopic data, copies of ^1H and ^{13}C NMR spectra of all compounds, and X-ray structures of the compounds **4ae** and **5oc** are included in the supporting information.

Acknowledgements

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Keywords: Propargyl alcohol• (Z)-Oxazolidin-2-one•3*H*-Oxazol-2-one•cyclization•rearrangement

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

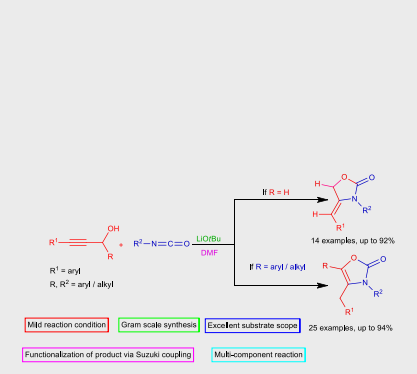
Layout 1:

FULL PAPER

Synthesis of 3,4,5-trisubstituted 3*H*-oxazol-2-ones and 3,4-disubstituted (Z)-oxazolidin-2-ones from substituted propargyl alcohols and aryl/alkyl isocyanates.

Suzuki coupling

Multi-component reaction



Key Topic*

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Page No.1 – Page No.4

LiO*t*Bu Promoted 5-*Exo*-dig Cyclization of Propargyl Alcohols and Isocyanates for the Synthesis of Multisubstituted 3*H*-Oxazol-2-ones and Oxazolidin-2-ones

*Multisubstituted 3*H*-oxazol-2-ones and (Z)-oxazolidin-2-ones

Layout 2:

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Text for Table of Contents

Key Topic*

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Page No. – Page No.

Title

*one or two words that highlight the emphasis of the paper or the field of the study

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[17] CCDC 1044385 (**4ae)** contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Center via www.ccdc.cam.ac.uk/data_request/cif

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