chemistry proceedings

Proceedings

Copper-, Cerium- and Dysprosium-Catalyzed Synthesis of Monosubstituted Allenes from *N,N*-Diisopropyl Substituted Propargylamines at Room Temperature †

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† Presented at the 25th International Electronic Conference on Synthetic Organic Chemistry, 15–30 November 2021.

Abstract: We have discovered for the first time that the [CuI–TIBAL], [$Ce_2(SO_4)_3$–TIBAL] and [$Dy_2(SO_4)_3$–TIBAL] catalytic systems makes it possible to prepare monosubstituted allenes from N,N-diisopropyl substituted propargylamines in dichloromethane or dichloroethane in high yield even at room temperature. Typically we used 0.2 equivalent of metal salt and 1-2 equivalents of TIBAL. This study demonstrates a remarkable activating effect of the TIBAL additive. In addition, the catalytic effect of lanthanide salts (Ce, Dy) on the conversion of propargylamines into monosubstituted allenes was discovered for the first time.

Keywords: allenes; ATA reaction; catalysis; copper-based catalysts; lanthanide-based catalysts propargylamines

Citation: Sadykova, F.T.; Zosim, T.P.; Ramazanov, I.R. Copper-, Cerium- and Dysprosium-Catalyzed Synthesis of Monosubstituted Allenes from *N,N*-Diisopropyl Substituted Propargylamines at Room Temperature. **2021**, *3*, x. https://doi.org/10.3390/xxxxx

Academic Editor(s): Julio A. Seijas

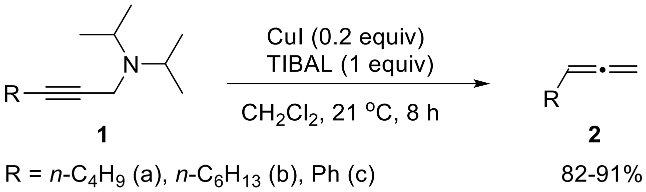
1. Introduction

Allenes have been demonstrated as synthetically versatile starting materials in organic synthesis. Allenation of terminal alkynes (ATA) reaction produces substituted allenes from terminal alkynes, carbonyl compounds, amines in the presence of Cu, Zn, Cd, Au, Ag and Pd salts [1]. All known ATA reactions, catalyzed by the salts of the above metals, take place at an elevated temperature from 40 °C (in the case of Au, Ag) [2,3] to 100 °C and higher (in the case of Cu, Zn, Cd) [4–7]. It is suggested that the formation of the allenes happens in a multistep process in which, at first, ATA reaction takes place and, the formed propargylamine then reacts further to generate the allene. Although the ATA reaction in some cases can be carried out at room temperature, not a single example of the conversion of propargylamine to allene at room temperature has been known. Recently we found that the reaction of *N,N*-diisopropyl-*N*-propargylamines with Et_3Al/MX_n system (MX_n = CuCl, CuBr, $ZnCl_2$, ZnI_2, CdI_2, $TiCl_4$, $ZrCl_4$, VCl_5, $TaCl_5$) in CH_2Cl_2 proceeds as an intramolecular red-ox hydride transfer affording *N*-dealkylated *N*-isopropyl-*N*-allylamines and acetone, allenes being formed as side products [8]. Herein we report the first positive results on the conversion of substituted propargylamines into allenes under the action of copper- and lanthanum-containing catalysts at room temperature.

2. Results and discussion

It was found that the reaction of *N,N*-diisopropyl substituted propargylamines 1a-b with 0.2 equivalent of CuI and 1 equivalent of *i*-Bu_3Al (TIBAL) in a dichloromethane at room temperature (21 °C) for 8 h gives substituted allenes 2 in high yield (82–91%)

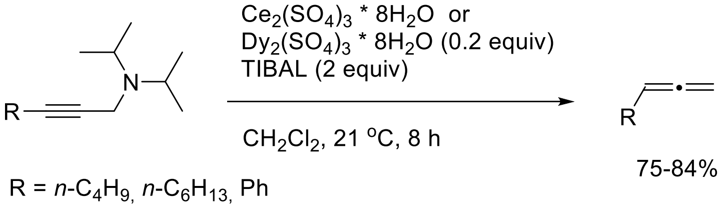
(Scheme 1). Similar results were obtained using dichloroethane instead of dichloromethane as a solvent. The reaction does not proceed in hexane, toluene, diethyl ether, THF, 1,4-dioxane. When Et_3Al is used instead of TIBAL and dichloromethane as a solvent, the character of the reaction does not change, but the yield of allene 2b dropped to 75%. At the same time when using *i*-Bu_2AlH, *i*-Bu_2AlCl, Et_2AlCl, $EtAlCl_2$, $AlCl_3$, the formation of allene 2b was not observed.



Scheme 1. The conversion of propargylamines into monosubstituted allenes under the action of [CuI–TIBAL] catalytic system.

Thus, the use of dichloromethane as a solvent and TIBAL as an additive reduced the reaction temperature to 21 °C. At the same time, earlier this transformation was usually carried out in the presence of CuI under conditions of boiling toluene (110 °C).

Another remarkable finding is the catalytic effect of lanthanide salts (Ce, Dy) on the conversion of propargylamines into monosubstituted allenes. We found that the reaction of *N,N*-diisopropyl substituted propargylamines 1a-b with 0.2 equivalent of $Ce_2(SO_4)_3$ * 8 H_2O or $Dy_2(SO_4)_3$ * 8 H_2O and 2 equivalent of TIBAL in a dichloromethane at room temperature (21 °C) for 8 h gives substituted allenes 2 in high yield (75–84%) (Scheme 2). Interestingly, lanthanide nitrates and chlorides did not show significant activity or selectivity in the synthesis of substituted allenes from *N,N*-diisopropyl substituted propargylamines.



Scheme 2. The conversion of propargylamines into monosubstituted allenes under the action of [$Ce_2(SO_4)_3$–TIBAL] or [$Dy_2(SO_4)_3$–TIBAL] catalytic system.

3. Conclusions

[CuI–TIBAL], [$Ce_2(SO_4)_3$–TIBAL] and [$Dy_2(SO_4)_3$–TIBAL] catalytic systems are efficient for transformation of *N,N*-diisopropyl substituted propargylamines into monosubstituted allenes in high yield at room temperature. The presented study demonstrates the promise of using organoaluminum compounds to create new metal complex systems for activation of C(sp^3)-H, C(sp^3)-C(sp) and C-N bonds in propargylic amines.

4. Experimental Part

The ^1H and ^{13}C NMR spectra were recorded on a Bruker Avance-500 (500 MHz) spectrometer in $CDCl_3$, chemical shifts were reported relative to TMS. Mass spectra were obtained on a Shimadzu GCMS QP2010 Plus GC-MS instrument (capillary column SPB-5 of 30 m × 0.25 mm, carrier gas–helium, from 40 to 300 °C at a rate 8 deg/min, temperature of vaporizer 280 °C, ion source temperature 200 °C, ionization energy 70 eV). Chromatographic analysis was carried out on a chromatograph Shimadzu GC-9A, GC-2014 [column of 2 m × 3 mm, stationary phase silicone SE-30 (5%) on Chromaton

N-AW-HMDS, from 50 to 270 °C, heating rate 8 deg/min, carrier gas-helium (47 mL/min)].

The Conversion of Propargylamines into MONOSUBSTITUTED allenes under the Action of [CuI–TIBAL], [$Ce_2(SO_4)_3$–TIBAL] and [$Dy_2(SO_4)_3$–TIBAL] Catalytic Systems

To a 25-mL argon-swept flask in an ice bath, equipped with a magnetic stirrer and rubber septa, was added 0.2 mmol of transition-metal salt suspended in CH_2Cl_2 (4 mL) and 1–2 mmol of TIBAL. To the solution was added dropwise 1 mmol of *N*,*N*-diisopropyl substituted propargylamine **1** and stirred at room temperature. Then, the reaction mixture was diluted with hexane (5 mL) and H_2O (3 mL) was added dropwise while cooling the reactor flask in an ice bath. The precipitate was filtered on a filter paper. The aqueous layer was extracted with diethyl ether (3 × 5 mL). The combined organic layers were washed with brine (10 mL), dried over anhydrous $CaCl_2$. Evaporation of solvent and purification of the residue by column chromatography (petroleum ether) gave substituted allene **2** as a colourless oil. The spectral parameters of the obtained compound are in good agreement with the published data.

Author Contributions: Conceptualization, F.T.S. and I.R.R.; methodology, T.P.Z.; software, I.R.R.; validation, T.P.Z.; formal analysis, I.RR..; investigation, F.T.S.; resources, I.R.R.; data curation, T.P.Z.; writing—original draft preparation, F.T.S.; writing—review and editing, I.R.R.; visualization, F.T.S.; supervision, F.T.S.; project administration, I.R.R.; funding acquisition, I.R.R. All authors have read and agreed to the published version of the manuscript.

Funding: The study was supported by a grant from the Russian Science Foundation (project No. 19-73-20128).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: The authors thank the Shared Facility Center, Zelinskii Institute of Organic Chemistry, Russian Academy of Sciences and the Shared Facility Center «Agidel», Institute of Petrochemistry and Catalysis, Russian Academy of Sciences, for the registration of NMR and mass spectra and for the elemental analysis of new compounds.

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