



Designing of thermally stable amide functionalized benzimidazolium perchlorate ionic liquid for transamidation of primary carboxamides

Prashant Narayan Muskawar^{a,c}, K. Thenmozhi^b, Pundlik Rambhau Bhagat^{a,*}

^a Organic Chemistry Division, School of Advanced Sciences, VIT University, Vellore, 632 014, India

^b Environmental and Analytical Chemistry Division, School of Advanced Sciences, VIT University, Vellore, 632 014, India

^c Department of Chemistry, Amolakchand Mahavidyalaya, Yavatmal, 445 001, India

ARTICLE INFO

Article history:

Received 17 October 2014

Received in revised form

29 December 2014

Accepted 7 January 2015

Available online 16 January 2015

Keywords:

Catalysis

Transamidation

Thermally stable

Amide functionalized

Benzimidazolium

ABSTRACT

In the present work, we have designed and synthesized a thermally stable catalyst based on functionalized benzimidazolium perchlorate ionic liquid and tested its efficacy towards metal free and solvent free transamidation of amides and amines. The ionic liquid comprising the perchlorate ion has shown remarkably better activity than those which contain other anions and accordingly a plausible mechanism for the catalytic activity is arrived. The developed catalytic system has shown excellent activity towards the transamidation of alicyclic and aromatic amines with acetamide, benzamide and *p*-nitrobenzamide under mild conditions. Furthermore, the transamidation of nicotinamide with benzylamine in presence of the ionic liquid catalyst was found to occur with very good yields and thus provides a facile route for the synthesis of pharmaceutically significant compounds. The catalyst has exhibited very good thermal stability upto 203 °C and very good recyclability upto 5 runs without significant loss in its activity.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

'Amide bond' is one of the most ubiquitous functional groups found in pharmaceuticals, polymers and natural products [1]. It has been predicted that nearly 25% of the synthetic drugs which include many top selling drugs such as valsartan, captopril, diltiazem, lidocaine, bupivacaine and acetazolamide possess atleast one amide unit [2]. Owing to the high significance and popularity of amide bond, the development of efficient amidation methods continues to be an imperative goal in synthetic organic chemistry. Conventionally, amide bond formation is achieved by the reaction of amines with carboxylic acid derivatives (chlorides, anhydrides, esters or acids) [3–5], aldehydes [6] or coupling reagents in stoichiometric quantities [7]. Methods like the oxidative coupling of alcohols with amines [8] and metal catalyzed rearrangement of oximes [9] have also been demonstrated as viable alternate for the conventional methods. However, there is still a lot of need to develop synthetic methodologies for making amides bonds with compounds comprising varieties of substituents.

In the recent years, transamidation is found to be a promisingly attractive route as it represents one of the most convenient

methods for exchanging the constituents of two different amide groups. Transamidation of amide with amine requires harsh reaction conditions (>250 °C), long reaction time as well as stoichiometric reagents to cleave the chemically tough amide bond due to intrinsic strength of the C–N amide bond collectively with the acidic N–H bond in amides [10]. Such harsh conditions are highly unfavorable when dealing with functionalized amide compounds. Alternatively, transamidation reactions based on enzyme catalysts are reported [11], whereas they have very limited scope and require development of task specific enzyme and long reaction time. In order to overcome these drawbacks, many researchers have attempted using homogeneous and heterogeneous catalysts like fourth group metal complexes (Ti, Zr, Hf) [12,20] and other metal based catalysts like Sc(OTf)₃ [13,14], Yb(OTf)₃ [15], Cu(OAc)₂ [16], CeO₂ [17], Fe-mont [18], Fe–H₂O [19], sulfated tungstate [20], and Nb₂O₅ spheres [21]. It has been observed that some of the inorganic complexes comprising Zirconium and Hafnium metal centers are not much effective for the transamidation of highly polar compounds because of their strong coordination to the metal centers [22]. Hence, attempts have been made to utilize homogeneous organocatalysts such as boron catalysts [23,24], Ph(OAc)₂ [25] l-proline [26], hydroxylamine hydrochloride [27] and majority of them are very effective for transamidation. However, major disadvantages with these catalysts include difficulty in recovery and recycling of catalyst for several runs, resulting in poor atom

* Corresponding author. Tel.: +91 9047289073; fax: +91 416 2240411.
E-mail address: drprbhagat111@gmail.com (P.R. Bhagat).

economy and possess potential environmental problems due to formation of large amount of waste. Hence, there is a continuous need for an effective and environmentally benign approach for the transamidation reactions and thus the development of a catalytic system that can offer higher yields under mild conditions is highly desired.

Ionic liquids (ILs) have become influential alternatives to conventional organic solvents and catalysts, due to their particular characteristics such as high thermal stability, undetectable vapor pressure, recyclability and tunability for specific tasks [28]. Among the variety of ILs used, benzimidazolium based ILs have been highly explored as they can be easily synthesized and used as an efficient, inexpensive and reusable catalyst in many organic reactions that include hydration reaction [29], synthesis of carboxylic esters [30], acetalization of aromatic aldehyde [31], multi-component reactions (MCRs) [32] and Benzoin reaction [33].

In the present work, we have attempted to synthesize functionalized benzimidazolium based ionic liquids (DAFBimILs) and to develop a catalytic system using these catalysts for the metal and solvent free transamidation reactions. To the best of our knowledge, there is no report on the catalytic activity of ILs towards transamidation reaction. Owing to the pivotal role of perchlorate in organic transformations like MCR reactions, substitution reactions, ring opening reactions, heterocyclic chemistry and carbohydrate chemistry [34], we have chosen perchlorate as the anion in the designing of our IL catalyst (DAFBimIL-3d). ILs comprising various other anions such as Cl, BF₄, PF₆, CF₃SO₃, and N(CF₃SO₂)₂ have also been synthesized and the catalytic activities are compared in order to demonstrate the role of perchlorate ion in determining the catalytic activity, based on which a mechanism has been proposed. The efficiency of the developed catalyst has been systematically tested towards the transamidation of varieties of amines and amides. Also, the thermal stability of the DAFBimIL-3d catalyst and its recyclability for the model reaction in presence of benzamide and benzylamine has been examined, which shows promising results.

2. Experimental

2.1. Materials

Benzimidazole, NaBF₄, KPF₆, LiClO₄, LiCF₃SO₃ and LiN(CF₃SO₂)₂ were obtained from Sigma Aldrich (India). Sodium hydride (60%), tetrahydrofuran (specially dried), n-hexane, p-phenylene diamine, p-toluene sulphonic acid (monohydrate), allylbromide, ethyl acetate, diethyl ether, dichloromethane, chloroform, sodium sulphate (anhydrous), sodium bicarbonate and all other amides and amines were purchased from SD Fine chemicals, India. Monochloroacetic acid and TLC plate Silica gel GF-254 were procured from Merck & Co. All the chemicals were used as received unless it is specified.

2.2. Characterization techniques

NMR spectra were recorded in DMSO-d₆, CDCl₃, D₂O on a Bruker spectrometer operating at 400 MHz and chemical shifts are given in ppm downfield from TMS ($\delta=0.00$). FT-IR spectra were obtained from IR Affinity-1 Shimadzu FT-IR spectrophotometer using KBr pellets. Ionic Mass spectral (MS) data were obtained on a Bruker Daltonics spectrometer using an Electrospray Ionization Quadrupole-Time of Flight (ESI-QTOF) analyzer and molecular weight of amide derivatives were determined using Perkin Elmer GC model-Clarus 680 (EI).

2.3. Synthesis and characterization of IL Catalysts

2.3.1. 3,3'-((1,4-phenylenebis(azanediyl))bis(2-oxoethane-2,1-diyl))bis(1-allyl-1H-benzo[d]imidazol-3-ium)chloride (DAFBimIL-3a)

1-Allyl benzimidazole was synthesized using reported method (Supporting Information, Scheme S1). The synthesis of ionic liquid DAFBimIL-3a was carried out based on the literature procedure [30]. 1-allylbenzimidazole (2.1 equivalents) and N,N'-(1,4-phenylene)bis(2-chloroacetamide) (1 equivalent) were charged with DMF in a 100 mL round bottom flask and the reaction mixture was stirred at 130 °C for 14 h (Scheme 1). The brownish solid was precipitated out, filtered in hot condition and washed repeatedly with ethyl acetate and diethyl ether to remove unreacted residues and finally the greyish solid was dried in vacuum at 60 °C for 2 h. Yield, 76.34%.

The syntheses of catalysts DAFBimIL-3b, 3c, 3d, 3e and 3f were carried out according to literature [35]. The DAFBimIL-3a (1 equivalent) was dissolved in distilled water and 2.1 equivalent aqueous solution of NaBF₄ or KPF₆ or LiClO₄ or LiCF₃SO₃ or LiN(CF₃SO₂)₂ were added dropwise with constant stirring for 15 min at room temp. The reaction mixture was allowed to stir for 5 h, after which the white solids 3b, 3c, 3d, 3e and 3f respectively precipitated out were collected by filtration and washed with distilled water over filter paper and finally dried in oven at 60 °C for 2 h.

All the prepared catalysts DAFBimIL-3b to 3f are insoluble in water except DAFBimIL-3a. During the conversion from DAFBimIL-3a to the respective IL, after filtering the catalysts, the filtrate was tested with silver nitrate solution to check the conversion. No precipitate was formed in all the cases ensuring the complete conversion of chloride to tetrafluoro borate, hexafluoro phosphate, perchlorate, trifluoromethane sulphonate and bis (trifluoromethane) sulphonimide).

2.4. Typical transamidation procedure

The amide (5.0 mmol), amine (5.5 mmol), and dicationic IL catalyst DAFBimIL-3d (1.0 mmol) were loaded in a 50 mL RB flask and the mixture was stirred at required temperature for particular time under nitrogen atmosphere. Progress of the reactions was monitored by TLC. After completion of the reaction, the transamide products were extracted in ethyl acetate (3 × 15 mL) and filtered to recover the catalyst. Ethyl acetate was removed using rotary evaporator and the obtained crude transamide products were purified using column chromatography and characterized by NMR and Mass spectrometry. Finally, the filtered solid IL catalysts were washed thoroughly with ethyl acetate, dried in vacuum at 60 °C for 2 h and then reused for the next run. All the transamidation reactions have been carried out at least three times to ensure the reproducibility of our results and the precision of our yields are presented in the respective tables.

3. Results and discussion

3.1. Catalytic studies

Based on the necessity of transamidation reaction to break the chemically tough amide bond, we have synthesized thermally stable dicationic amide functionalized benzimidazolium ionic liquids (DAFBimILs) with different anions such as Cl, BF₄, PF₆, ClO₄, CF₃SO₃, and N(CF₃SO₂)₂. We have examined the catalytic activity of our DAFBimILs towards the solvent free synthesis of different kinds of amides. In order to optimize the reaction conditions, a model reaction was carried out using benzamide and benzylamine under solvent free condition (Scheme 2).

Download English Version:

<https://daneshyari.com/en/article/39385>

Download Persian Version:

<https://daneshyari.com/article/39385>

[Daneshyari.com](https://daneshyari.com)