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Short communication

Transamidation of carboxamides with amines over nanosized zeolite beta under solvent-free conditions



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ABSTRACT

A highly efficient approach to transamidation of carboxamides with amines over nanosized zeolite beta under solvent-free conditions has been successfully demonstrated. Transamidation of a variety of amides with amines produced the respective *N*-alkyl amides in moderate to excellent yields.

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Amide bond is one of the most important linkages in nature and also they have been intensively investigated in organic synthesis [1–3]. Furthermore, it represents a significant functional group that has ubiquitous applications in natural products, pharmaceuticals, fine chemicals and polymers [4]. In general, substituted amides are synthesized by the coupling of carboxylic acid derivatives with amines or aryl/alkyl halides with primary amides [5–6]. However, these procedures have some drawbacks, such as the lability of the activated acid derivatives and tedious experimental procedures [7]. Alternatively, some name reactions (i.e., Ritter [8], Schmidt [9], Beckmann [10], Ugi [11], Wolff [12], etc.) and metal catalyzed reactions have been developed for their synthesis [13–16].

However, reactions of amide group with nucleophiles usually requires harsh reaction conditions due to the poor electrophilic character of the amide group, which makes the transamidation of amides with amines, an alternative and attractive method for obtaining the substituted amides. Amides are relatively inert when compared with other acyl donors and therefore uncatalyzed transamidation reactions require forcing conditions [17–18]. Y. L. Khmelnitsky et al. reported the enzyme-mediated transamidation, but it requires highly evolved enzymes, long reaction times and limited scope [19]. To overcome these drawbacks, new homogeneous [20–24] and heterogeneous [25–30] catalysts have been recently reported. In present days, environmental and economical considerations have raised strong interest in redesigning commercially important processes to avoid the use of harmful reagents and the generation of toxic waste. In this regard, heterogeneous catalysts can play a key role in the development of ecofriendly processes in petroleum chemistry and production of chemicals. Unfortunately, most of the heterogeneous methods suffer from one or more disadvantages such as limited substrate scope, harsh reaction conditions, need of a solvent and strong base. Considering these, the development of environmentally benign and efficient transamidation approach towards the synthesis of higher amides is still challenging.

Zeolites are uniform microporous crystalline materials and have widespread applications both in petroleum and fine chemical industries due to their unique physical and chemical properties, such as uniform channel size, large internal surface area, unique molecular shape selectivity, strong acidity and good thermal/hydrothermal stability. Zeolite H β has received much attention because of the large available micropore volume, large-pore channel system and the presence of active sites in different concentrations that are useful in a number of acid-catalyzed reactions. However, zeolites often show inadequate activity and/or fast deactivation because of poor diffusion efficiency [31]. The slow transport in the zeolite micropores leads to unwanted secondary side reactions or slow reaction rates. In order to get additional benefits from the unique sorption and shape-selectivity effects in the micropores, the diffusion path length in the micropores should be extremely small.

Nanozeolites are a type of zeolites which have narrow particle size distributions with sizes of less than 200 nm. Reducing the particle size from micrometer to nanometer scale, leads to a significant change in



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Table

Table 1

Optimization of reaction conditions for the transamidation of benzamide with benzylamine a

Ph $NH_2^+ Ph$ NH_2 $Catalyst Ph$ Ph Ph Ph Ph Ph						
1a	24 H	3a				
Entry	Catalyst	Temp °C	Yield ^b (%)			
1	HZSM (40)	135	26			
2	H-mordenite	135	57			
3	HY	135	36			
4	NaY	135	8			
5	Нβ	135	72			
6	MCM-41	135	49			
7	Montmorillonite K10	135	56			
8	Absence of catalyst	135	25			
9	Nanosized zeolite beta	135	92			
10	Nanosized zeolite beta	100	46			
11	Nanosized zeolite beta	120	70			
12	Nanosized zeolite beta	140	92			
13	Nanosized zeolite beta	135	78 ^c			
14	Nanosized zeolite beta	135	88 ^d			
15	Nanosized zeolite beta	135	93 ^e			
16	Nanosized zeolite beta	135	68 ^f			
17	Nanosized zeolite beta	135	40 ^g			

e 3				

Transamidation of benzamide with different amines over nanosized zeolite beta.^a

Ph NH ₂ +	$R^{n}NH_2 -$	nanosized zeolite beta 135 °C, neat, 24 h → Ph H R
Entry	R	Yield ^b (%)
1	4-MeOC ₆ H ₄	91
2	4-MeC ₆ H ₄	93
3	$4-FC_6H_4$	96
4	4-ClC ₆ H ₄	97
5	2-ClC ₆ H ₄	90
6	4-BrC ₆ H ₄	96
7	1Me-Ph	45
8	2-Napthyl	62
9	3-C ₅ H ₄ N	92
10	2-C ₄ H ₃ O	60
11	$2-C_4H_3S$	62
12	CH ₂ -Ph	65
13	Cyclohexyl	60
14	C5H11	62
15	$C_{15}H_{31}$	58

^a Reaction conditions: benzamide (1 mmol), amines (2 mmol), nanosized zeolite beta (100 mg), 135 °C, 24 h.

simple and efficient method for the transamidation of amides with

amines over nanosized zeolite beta under solvent-free conditions. To

the best of our knowledge, nanosized zeolite beta catalyzed

transamidation has been not yet reported. Nanosized zeolite beta was

prepared according to the procedure described in our earlier report, which was systematically characterized by various spectroscopic techniques (SEM, TEM, XRD, FT-IR, MAS-NMR, NH₃-TPD and ²⁷Al NMR) [35].

In the initial investigation, the reaction of benzamide with

benzylamine (2 equiv.) was selected as a model system to find out the

best reaction conditions. In order to choose the best catalyst first, the re-

action was subjected with various zeolites, MCM-41 and montmorillonite K10 at 135 °C (Table 1, entries 1–7). Among the various catalysts

investigated, HB zeolite exhibited the best catalytic activity and afforded

^b Isolated yields were calculated based on benzamide.

^a Reaction conditions: **1a** (1 mmol), **2a** (2 mmol), catalyst (100 mg), 135 °C, 24 h. b Isolated vields

^e 2a (2.5 mmol).

^f Catalyst (50 mg).

g Catalyst (25 mg).

material characteristics and their applications in catalysis and adsorption. The number of atoms in the unit cell increases as particle size decreases and therefore, nanozeolites have large external surface area. The diffusion path lengths also shortened in nanozeolites as compared to that in the conventional micrometer zeolites [32-34].

In continuation of our efforts towards the development of novel and eco-friendly synthetic protocols using zeolites [35] herein, we report a

Table 2

Transamidation	of	carboxamides	with	benzvlamine	over	nanosized	zeolite	beta. ^a

$\frac{O}{R - NH_2} + Ph - NH_2 \xrightarrow{\text{nanosized zeolite beta}}{135 \text{ °C, neat, 24 h}}$	R N Ph	
Entry	R	Yield ^b (%)
1 2 3 4 5 6 7 8 9 10 11 11 12 13	Ph 4-MeOC ₆ H ₄ 3-MeOC ₆ H ₄ 4-MeC ₆ H ₄ 3-MeC ₆ H ₄ 4-BrC ₆ H ₄ 2-ClC ₆ H ₄ 4-NO ₂ C ₆ H ₄ 3-NO ₂ C ₆ H ₄ 3-CF ₃ C ₆ H ₄ PhCHCH 2-C ₄ H ₅ S 2-C ₅ H ₄ N	92 72 94 74 73 82 65 65 68 93 82 65 98
14 15 16 17 18	$3-C_{5}H_{4}N$ $2,5-C_{4}H_{3}N_{2}$ H CH_{3} $C_{2}H_{5}$	68 96 98 ^c 99 ^c 99 ^c

Reaction conditions: amides (1 mmol), benzylamine (2 mmol), nanosized zeolite beta (100 mg), 135 °C, 24 h.

^b Isolated yields were calculated based on amide.

^c Reactions were carried out at 100 °C.

²a (1 mmol).

^d 2a (1.5 mmol).

Table 4

Transamidation of benzamide with benzylamine - reusability of the catalyst^a.

Ph NH ₂ +	Ph ∕ NH ₂ nanosized zeolite beta 135 °C, neat, 24 h	Ph N Ph	_
Entry	Cycle	Yield ^b (%)	
1	First	92	
2	Second	91	
3	Third	91	
4	Fourth	88	

^a Reaction conditions: benzamide (1 mmol), benzylamine (2 mmol), nanosized zeolite beta (100 mg).

^b Isolated yields.

the corresponding secondary amide in 72% yield (Table 1, entry 5). Further, to improve the yield of **3a**, we examined the reaction with nanosized zeolite beta under similar conditions, which produced much higher yield (92%) as compared to other catalysts (Table 1, entry 9).

Once nanosized zeolite beta was found as the best catalyst, the influence of the reaction temperature was studied. By varying the temperature from 135 to 100 °C, a gradual decreasing in yield (92 to 46%) was observed and further increase in temperature did not have any accountable effect on the yield (Table 1, entries 9–12). Next, we studied the effect of mole ratio of benzamide to benzylamine from 1:1 to 1:2.5 under the similar conditions, which had a considerable effect on the product yield (Table 1, entries 13–15). The present reaction was also conducted with different amounts of catalyst and it was revealed that 100 mg of catalyst gave the best results (Table 1, entries 9 and 16–17). In the absence of catalyst, the corresponding product was obtained in lower yield (25%) (Table 1, entry 8). As can be seen from the above presented results, the optimized reaction conditions to acquire the highest yield for this transamidation reaction are 1:2 mol ratio of benzamide to benzylamine at 135 °C over nanosized zeolite beta (100 mg).

To explore the scope and limitations of the present system under the optimized conditions, a variety of amides were reacted with benzylamine, furnished moderate to excellent yields of the corresponding secondary amideswithhighdegreeoffunctionalgrouptolerance(Table2).Inordertodetermine the influence of substitution on the aromatic ring of benzamide with this reagent system, we have carried out the reaction of different substituted benzamides with benzylamine. Activating groups present on aromatic ring of benzamide afforded good to excellent yields of the respective secondary amides (Table 2, entries 2-5). Deactivating groups present on the aromatic ring of benzamide yielded moderate to excellent yields of the corresponding secondary amides (Table 2, entries 6-10). Cinnamamide reacted smoothly and furnished the corresponding product in 82% yield (Table 2, entry 11). Heteroaryl amides such as, thiophen-2carboxamide, picolinamide, nicotinamide and pyrazine-2-carboxamide alsoprovided the corresponding products in 65–98% yields (Table 2 entries 12-15). Further, we examined the transamidation of a liphatic primary amides with benzylamine, which gave the respective products in excellent yields (Table 2, entries 16–18).

To expand further scope of the reaction, a series of amines was allowed to react with benzamide to give the corresponding products



Scheme 1. Plausible reaction mechanism.

in moderate to excellent yields under similar conditions (Table 3). Activating groups present on aromatic ring of benzylamine yielded the respective products in 91% and 93% yields, respectively (Table 3, entries 1 and 2). Halo substituted benzylamines such as, 4-fluorobenzylamine, 4-chlorobenzylamine, 2-chlorobenzylamine and 4-bromobenzylamine afforded the corresponding secondary amides in 90-97% yields (Table 3 entries 3-6). 1-Phenylethylamine and 1napthylmethylamine provided the corresponding products in 45% and 62% yields, respectively (Table 3, entries 7 and 8). Heteroaromatic amines such as, 3-picolylamine, furfurylamine and 2thiophenemethylamine gave the desired products in 60-92% yields (Table 3, entries 9–11). In the case of 2-phenethylamine, the corresponding product was obtained in 65% yield (Table 3, entry 12). Further, we also investigated the aliphatic primary amines with benzamide and afforded the respective products in good yields (Table 3, entries 13–15).

The catalyst (nanozeolite) was easily separated from the reaction mixture by simple filtration. Further, recycling of catalyst was carried out by performing the reaction of benzamide with benzylamine under standard reaction conditions and the reused catalyst showed consistent activity even after fourth cycle of reuse (Table 4). The catalyst was highly crystalline before and after the reaction, which was confirmed by XRD (see the ESI Fig. S1).

Based on the literature reports [29,31–33], the plausible reaction mechanism for the transamidation of carboxamides with amines over nanosized zeolite beta is illustrated in Scheme 1. It is assumed that amide is adsorbed on the Bronsted acid sites of zeolite, which subsequently reacts with amine followed by elimination of ammonia yields the desired transamidation product.

In summary, an effective and green protocol for the transamidation of carboxamides with amines over nanosized zeolite beta under solvent-free conditions has been successfully developed. Notable advantages offered by this method are absence of organic solvent, broad substrate scope, high atom economy, use of non-hazardous and reusable catalysts, higher yields of the desired products and simple workup procedure, which makes it an attractive and useful alternative to the existing methods.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx. doi.org/10.1016/j.catcom.2016.04.004.

References

- [1] J.S. Carey, D. Laffan, C. Thomson, M.T. Williams, Org. Biomol. Chem. 4 (2006) 2337.
- [2] E. Valeur, M. Bradley, Chem. Soc. Rev. 38 (2009) 606.
- [3] V.R. Pattabiraman, J.W. Bode, Nature 480 (2011) 471.
- [4] X.X. Zhang, W.T. Teo, P.W.H. Chan, J. Organomet. Chem. 696 (2011) 331.
- [5] B. Gnanaprakasam, D. Milstein, J. Am. Chem. Soc. 133 (2011) 1682.
- [6] A. Zare, A. Hasaninejad, A.R. Moosavi-Zare, A. Parhami, A. Khalafi-Nezhad, Asian J. Chem. 21 (2009) 1090.
- [7] R.G. Kalkhambkar, S.N. Waters, K.K. Laali, Tetrahedron Lett. 52 (2011) 867.
- [8] J.J. Ritter, P.P. Minieri, J. Am. Chem. Soc. 70 (1948) 4045.
- [9] R.F. Schmidt, Ber. Dtsch. Chem. Ges. 57 (1924) 704.
- [10] E. Beckmann, Ber. Dtsch. Chem. Ges. 89 (1886) 988–993.
- [11] I. Ugi, Angew. Chem. 74 (1962) 9.
- [12] L. Wolff, Justus Liebigs Ann. Chem. 384 (1912) 25.
- [13] M. Miyasaka, K. Hirano, T. Satoh, R. Kowalczyk, C. Bolm, M. Miura, Org. Lett. 13 (2011) 359.
- [14] B. Xiao, T.J. Gong, J. Xu, Z.J. Liu, L. Liu, J. Am. Chem. Soc. 133 (2011) 1466–1474.
- [15] K.M. Driller, S. Prateeptongkum, R. Jackstell, M. Beller, Angew. Chem. Int. Ed. 123 (2011) 558.
- [16] N. Marion, S.P. Nolan, Acc. Chem. Res. 41 (2008) 1440.
- [17] A. Galat, G. Elion, J. Am. Chem. Soc. 65 (1943) 1566.
- [18] M. Hutchby, C.E. Houlden, M.F. Haddow, S.N.G. Tyler, G.C. Lloyd-Jones, K.I. Booker-Milburn, Angew. Chem. Int. Ed. 51 (2012) 548.
- [19] M.V. Segreeva, V.V. Mozhaev, J.O. Rich, Y.L. Khmelnitsky, Biotechnol. Lett. 22 (2000) 1419.
- [20] S.E. Eldred, D.A. Stone, S.H. Gellman, S.S. Stahl, J. Am. Chem. Soc. 125 (2003) 3422.

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- [21] C.L. Allen, B.N. Atkinson, J.M.J. Williams, Angew. Chem. Int. Ed. 51 (2012) 1383.
- [22] N. Atkinson, A.R. Chhatwal, H.V. Lomax, J.W. Walton, J.M.J. Williams, Chem. Commun. 48 (2012) 11626.

- [23] S.N. Rao, D.C. Mohan, S. Adimurthy, Org. Lett. 15 (2013) 1496.
 [24] R. Vanjari, B.K. Allam, K.N. Singh, RSC Adv. 3 (2013) 1691.
 [25] M. Tamura, T. Tonomura, K. Shimizu, A. Satsuma, Green Chem. 14 (2012) 717.
- [26] M. Shi, S.C. Cui, Synth. Commun. 35 (2005) 2847.
 [27] M.D. Ayub Ali, S.M.A.H. Siddiki, K. Kon, K. Shimizu, Tetrahedron Lett. 55 (2014) 1316.
- [28] S.P. Pathare, A.K.H. Jain, K.G. Akamanchi, RSC Adv. 3 (2013) 7697.

- [29] S. Nageswara Rao, D. Chandra Mohan, S. Adimurthy, RSC Adv. 5 (2015) 95313.
 [30] S. Nageswara Rao, D. Chandra Mohan, S. Adimurthy, Green Chem. 16 (2014) 4122.
 [31] G. Majano, S. Mintova, O. Ovsitser, B. Mihailova, T. Bein, Microporous Mesoporous Mater. 80 (2005) 227.

- Mater. 80 (2005) 227.
 [32] S. Mintova, T. Bein, Microporous Mesoporous Mater. 50 (2001) 159.
 [33] G. Yang, X. Zhang, S. Liu, K.L. Yeung, J. Wang, J. Phys. Chem. Solids 68 (2007) 26.
 [34] S. Mintova, J.P. Gilson, V. Valtchev, Nanoscale 5 (2013) 6693.
 [35] M.M. Reddy, M.A. Kumar, P. Swamy, M. Naresh, K. Srujana, L. Satyanarayana, A. Venugopal, N. Narender, Green Chem. 15 (2013) 3474.