Contents lists available at SciVerse ScienceDirect



Journal of Molecular Catalysis A: Chemical



journal homepage: www.elsevier.com/locate/molcata

Mg(BF₄)₂ doped in [BMIm][BF₄]: A homogeneous ionic liquid-catalyst for efficient synthesis of 1,8-dioxo-octahydroxanthenes, decahydroacridines and 14-aryl-14*H*-dibenzo[*a*,*j*]xanthenes

Kurosh Rad-Moghadam*, Seyyedeh Cobra Azimi

Chemistry Department, University of Guilan, 41335-19141 Rasht, Iran

ARTICLE INFO

Article history: Received 4 April 2012 Accepted 23 July 2012 Available online 31 July 2012

Keywords: Xanthenes Acridines Ionic liquid Magnesium cation Homogeneous catalyst

ABSTRACT

A homogeneous ionic liquid made up of 0.5 mol% Mg(BF₄)₂ doped in [BMIm]BF₄ was obtained from a mixture of MgCl₂ and [BMIm]Cl subjected to anion exchange with NaBF₄. The ionic liquid efficiently catalyzes the synthesis of 1,8-dioxo-octahydroxanthenes, 14-aryl-14H-dibenzo[a,j]xanthenes, and 1,8dioxo-decahydroacridines, giving excellent yields in short periods of time at 80 °C. The integrity of the ionic liquid remains reasonably unchanged when it is separated from the reaction mixture by water extraction, as it can be recycled several times without any loss of activity in each of the title syntheses. Magnesium cation, though in low concentration, appeared as an essential element of this ionic liquid catalysis, perhaps due to its non-coordinated existence giving rise to a promoted Lewis acidic characteristic. Application of this new homogeneous catalyst system offered the advantages of high yields, short reaction times, and easy workup procedure compared to the conventional methods of the syntheses.

© 2012 Elsevier B.V. All rights reserved.

1. Introduction

Though ionic liquids belong to the class of strongly polar solvents capable to dissolve both organic and inorganic materials, they may be designed non-coordinating, in contrast to polar molecular solvents, to avoid any undesirable binding to metal catalysts in pre-transition states and hence offer great advantages in terms of catalysis and selectivity [1-4]. In such conditions, metal catalysts exist relatively uncomplexed and their almost bare cations are expected to have higher activity than in traditional polar organic solvents. Application of the ionic liquids composed of weakly coordinating anions, such as BF_4^- and PF_6^- , together with suitably substituted cations often resulted in a pronounced chemical reactivity of the dissolved catalysts and therefore led to improvement of both reactivity and selectivity [5–7]. Moreover, ionic liquids by virtue of their organic and ionic nature are potent solvents to exert nearly all kinds of interactions on reacting species including transition states. Usually, these interactions alternatively give rise to considerable reductions in activation energies either by stabilization of transition states or destabilization of reactants. As a result, the catalytic activity of ionic liquids strongly depends on their chemical and physical

* Corresponding author. E-mail address: radmm880@gmail.com (K. Rad-Moghadam). properties and in turn on the properties of their cationic and anionic constituents. Another aspect of ionic liquids is their potential to bias reaction equilibriums in favor of products. For example, hydrophilic ionic liquids tend to facilitate dehydration of intermediate products by stabilizing the eliminated water molecules [8]. Owing to these fascinating features associated with easy phaseseparation from reaction mixtures, ionic liquids have achieved an outstanding position as a new generation of solvents in the area of organic synthesis. In continuation of our studies focused on development of ionic liquids as catalysts in synthesis of organic compounds [9–12], herein we describe the efficiencies of the ionic liquid composed of $Mg(BF_4)_2$ doped in $[BMIm][BF_4]$ for promoting the synthesis of 1,8-dioxo-octahydroxanthenes, 14-aryl-14Hdibenzo[a,j]xanthenes and 1,8-dioxo-decahydroacridines.

Xanthenes and benzoxanthene derivatives are the parent frameworks found in a large number of naturally occurring as well as synthetic products possessing prominent positions in medicinal chemistry [13,14]. Xanthenediones are likewise special structural units constituting various natural products [15] and being used as versatile synthons, because of inherent reactivity of their inbuilt pyran ring [16]. Consequently, many alternative catalysts such as p-toluenesulfonic acid [17], p-dodecylbenzenesulphonic acid [18], triethylbenzylammonium chloride [19], diammoniumhydrogen phosphate under various conditions [20], sulfonic acid under ultrasonic irradiation [21], InCl₃/ionic liquid [22], Fe³⁺-montmorilonite [23], NaHSO₄-SiO₂ or silica chloride [24], amberlyst-15 [25], P₂O₅

^{1381-1169/\$ -} see front matter © 2012 Elsevier B.V. All rights reserved. http://dx.doi.org/10.1016/j.molcata.2012.07.026

Optimization of reaction conditions for the model reactants, 5,5-dimethyl-1,3-cyclohexanedione and 4-chlorobenzaldehyde.



Entry	Ionic liquid ^a	Temperature (°C)	Time	Yield (%) ^b
1	[Bmim][BF ₄]–0.5 mol% Mg(BF ₄) ₂	20	12 h	Trace
2	[Bmim][BF ₄]-0.5 mol% Mg(BF ₄) ₂	30	10 h	15
3	[Bmim][BF ₄]-0.5 mol% Mg(BF ₄) ₂	40	7 h	25
4	[Bmim][BF ₄]-0.5 mol% Mg(BF ₄) ₂	50	3 h	42
5	[Bmim][BF ₄]-0.5 mol% Mg(BF ₄) ₂	60	1.5 h	68
6	[Bmim][BF ₄]-0.5 mol% Mg(BF ₄) ₂	70	40 min	80
7	[Bmim][BF ₄]-0.5 mol% Mg(BF ₄) ₂	80	15 min	87
8	[Bmim][BF ₄]-0.5 mol% Mg(BF ₄) ₂	90	15 min	87
9	[Bmim][BF ₄]	80	12 h	-
10	[Bmim][Cl]	80	12 h	-
11	[Bmim][BF ₄]–0.5 mol% MgCl ₂	80	4 h	51
12	Neat ^c	80	12 h	45

^a The reactions were carried out in the presence of 1 mL of the ionic liquid.

^b Isolated yields.

^c The reaction was run under neat condition.

or InCl₃ [26], montmorilonite [27], and silica sulfuric acid [28] have been used for the synthesis of xanthenedione derivatives. However, each of the methods have their own merit some methods suffer from long reaction times, low yields, use of large quantities of volatile organic solvents, harsh reaction conditions, and tedious workup. Therefore, development of an alternative efficient and versatile method for synthesis of these valuable compounds could be so worthwhile, 1,4-Dihydropyridines represent an important class of compounds which are found in many sorts of biologically active compounds such as vasodilators, bronchodilators, antiatherosclerotics, antitumors, geroprotectives, hepatoprotective agents [29], and calcium channel blockers [30,31]. 1,8-Dioxodecahydroacridines with inbuilt 1,4-dihydropyridine nucleus have shown very high lasing efficiencies [32] and hence used as photoinitiators [33]. As a consequence of these interesting properties. a large library of acridinediones has been synthesized by the reaction of aldehydes with 2 equivalents of 1,3-cyclohexanedione or 5,5-dimethyl-1,3-cyclohexanedione and appropriate amines via various methods [34-38].

2. Results and discussion

Magnesium constitutes the central element of several frequently used efficient catalysts and involves, at normal oxidation state, in bioactivities of living organisms implying its bio-friendlier consistency. Despite of these fascinating features and several recent reports on utility of magnesium compounds as catalysts [39-41], so far the catalysis capacity of magnesium cation has not been examined in ionic-liquid medium. It seems reasonable to expect that Mg²⁺ cations dissolved in less coordinative ionic medium would have intensed chemical activity. To deal with this idea, we required a homogeneous solution of Mg²⁺ in an ionic liquid composed of a bulky organic cation and an almost non-coordinating anion. In this regard, a room temperature ionic liquid was prepared via saturation of [BMIm]BF₄ with Mg(BF₄)₂. Atomic absorption analysis of this liquid has shown that it is 0.5 mol% in concentration of dissolved Mg²⁺ ion. This low saturated concentration of Mg²⁺ is not more surprising by considering that it is a hard cation being dissolved mostly

in favor of increased entropy and without receiving significant solvating interactions with the ionic liquid. The new ion-ion electrostatic bondings created on dissolution of Mg²⁺ ions in [BMIm]BF₄ are rather weak forces assuming to be insufficient to completely cover the lattice energy of the initial magnesium salt. It was initially difficult to expect that such a low-concentration of Mg²⁺ ions could impart any considerable catalysis activity to the ionic liquid. However, the ionic solution appeared as a very efficient catalyst when applied to three defined acid-demanded trial reactions. Certainly, the catalysis activity is attributed to the dissolved Lewis acidic Mg²⁺ ions, as the reactions have not remarkably proceeded in the Mg²⁺-free ionic liquid, [BMIm]BF₄. Activity of the catalyst was first evaluated for synthesis of xanthene-1,8-diones by examining its impact on the rate and yield of the model reaction between 5.5-dimethyl-1.3-cyclohexanedione **1** and 4-chlorobenzaldehyde. To determine the optimum condition and also to discerning the main element of the catalysis, the reaction was carried out at variable temperatures and alternatively in closely related ionic liquids (Table 1). It could be seen that the best result was obtained with 1 mL of [BMIm][BF₄]–0.5 mol% Mg(BF₄)₂ at 80 °C (Table 1, entry 7). Monitoring by TLC has shown no detectable progress of the reaction in the ionic liquids [BMIm]BF₄ and [BMIm]Cl. These observations are addressing the catalysis interactions to Mg²⁺ ion and not owing to strictly ionic nature of the catalyst. Interestingly, the model reaction gave low yield in even long time when it was run at 80°C in the ionic liquid [BMIm][BF₄]–0.5 mol% MgCl₂ being made simply by dissolving 0.5 mol% MgCl₂ in [BMIm][BF₄]. In this ionic solution, the Mg^{2+} ions are assumed to be relatively tethered by coordination with chloride ions. This finding clearly lends considerable credence to hypothesis that Mg²⁺ ion gains an enhanced catalytic activity in the non-coordinating medium of [BMIm]BF₄.

After optimizing the conditions, the scope of method was successfully testified by using a wide range of aromatic aldehydes at $80 \,^{\circ}$ C. The results, summarized in Table 2, delineate the efficiencies of the method in terms of fairly high yields of the products and short reaction times.

To compare the efficiencies of this ionic liquid system with the previously reported catalysts in synthesis of xanthenes, we have

Synthesis of 1,8-dioxo-octahydroxanthenes by the reaction of 5,5-dimethyl-1,3-cyclohexanedione and aromatic aldehydes in [BMIm][BF₄]-0.5 mol% Mg(BF₄)₂ at 80 °C.



^a Isolated yield.

^b Refs. [18,23].

gathered the results obtained by using this ionic liquid and those reported on application of some other catalysts to the synthesis of 9-(2-chlorophenyl)-1,8-dioxo-octahydroxanthene **3b** in Table 3. As is shown in Table 3, effecting the reaction in the ionic liquid appreciably improves the synthesis in several aspects featured by some other methods, for example higher temperatures, longer reaction times, lower yields, and limitation of the substrate applicability. The reaction goes to complete in shorter time and affords high yield when is run in the [BMIm]BF₄–0.5 mol% Mg-(BF₄)₂ at 80 °C.

Further evidences on efficiency of this catalyst were obtained by application of the ionic system to the synthesis of dibenzo[a_j]xanthenes using the pseudo-three-component reaction between 2-naphthol and various aldehydes at 80 °C. As is shown in Table 4, the reactivity of 2-naphthol with aldehydes in the ionic liquid spans a considerable range, affording a variety of 14-substituted-14*H*-dibenzo[a_j]xanthenes. It is noteworthy that the presence of electron-donating and electron-accepting as well as steric demanded substituents on the reacting aldehydes does not affect the overall yield and rate of the reactions sensibly.

However specifying the exact catalysis events through the formation of xanthenes awaits for further investigations, a reasonable interpretation for catalytic actions of the ionic liquid based on a more accepted mechanism of the reactions [25,26] was depicted in Scheme 1. The xanthene synthesis presumably initiates by nucleophilic addition of the substrate phenol **4** or the enol **1** on the reactant aldehyde activated by magnesium cation. The resulting adduct **6** undergoes dehydration to give the key enone intermediate **7** which is likely activated by magnesium cation to follow a Michael type addition onto the second molecule of **1** or **4**. The later reaction would produce the bis-phenol or alternatively the bis-enol intermediate **8** ensuing a magnesium cation mediated dehydration to afford the xanthenes **3** or **5**.

Encouraged by these results, we aimed to evaluate the catalytic method for the reaction of 5,5-dimethyl-1,3-cyclohexanedione **1**, an aldehyde, and NH₄OAc in 1 mL of [BMIm][BF₄]–0.5 mol% Mg(BF₄)₂ at 80 °C to afford 1,8-dioxo-decahydroacridine derivatives **9a–j**. Again the reactions went to completion within short periods of time to give fairly high yields of the products. Here also the aromatic aldehydes containing electron-donating or electron-withdrawing groups afforded fairly high yields of 1,8-dioxo-decahydroacridines (Table 5). All the products are known compounds, and their identity were verified by IR and ¹H NMR spectroscopic analysis as well as comparison of their physical data with those of authentic samples.

Workup procedure is so simple for all the syntheses and includes addition of water at the end of reaction, filtration, and finally recrystallization of the products from ethanol. The ionic liquid was removed simply by dissolution in water added to the reaction mixture and then recovered by evaporation of water at 80 °C under reduced pressure. The catalytic activity of the ionic liquid system remained evidently unaltered even after five successive retrieval and when reused in the same synthesis (Table 6).

3. Experimental

All the solvents and reagents were purchased from Fluka or Merck chemical companies. Melting points were measured on an Electrothermal apparatus and are uncorrected. IR spectra were obtained in KBr discs on a Shimadzu IR-470 spectrometer. ¹H NMR spectra were recorded on a BRUKER DRX-300 AVANCE spectrometer at 300.13 MHz.

Table 3

Synthesis of 9-(2-chlorophenyl)-1,8-dioxo-octahydroxanthene **3b** using [BMIm][BF₄]-0.5 mol% Mg(BF₄)₂ and comparison with some other reported catalysts.

Entry	Catalyst/solvent/conditions	Time (min)	Yield (%)	References
1	NaHSO4·SiO2/CH3CN/reflux	390	90	[24]
2	Silica chloride/CH3CN/reflux	360	92	[24]
3	Fe ³⁺ -montmorillonite/solvent-free/100 °C	360	92	[23]
4	Amberlyst-15/CH ₃ CN/reflux	300	90	[25]
5	p-Dodecylbenezenesulfonic/H ₂ O/reflux	360	90	[18]
6	Montmorillonite K10/solvent-free/120°C	60	85	[27]
7	[BMIm]BF ₄ -0.5 mol% Mg(BF ₄) ₂ /neat/80 °C	15	92	This work

C		1 1 477 11	· · · · · · · · · · · · · · · · · · ·		1000 + 10000 + 10000 + 10000 + 10000 + 1000 + 1000 + 1000 + 1000 + 1000 + 100	
~	n n n n n n n n n n	71_14H_01060701	n n n n n n n n n n			
0	finites of 14 and	yi i Hii uibciizoj	u, j Mantinenes catar	yzcu by jbiviiiii	[[DI 4] 0.5 mol/6 wig(DI 4)) at 00 C.	



Product ^a	Ar	Time (min)	Yield (%) ^b
5a	C ₆ H ₅	15	95
5b	2-ClC ₆ H ₄	15	98
5c	3-ClC ₆ H ₄	15	86
5d	4-ClC ₆ H ₄	15	94
5e	3-NO ₂ C ₆ H ₄	30	98
5f	$4-NO_2C_6H_4$	30	98
5g	4-FC ₆ H ₄	30	84
5h	4-HOC ₆ H ₄	30	98
5i	$4-H_3CC_6H_4$	30	95
5j	$4-H_3COC_6H_4$	30	91
5k	2,4-(Cl) ₂ C ₆ H ₃	30	85
51	Cinnamaldehyde	30	95

^a All the products were characterized by comparison of their spectroscopic and physical data with those reported in literature.

^b Refs. [17,25,26].



Scheme 1. A plausible mechanism for synthesis of xanthenes mediated by catalysis of magnesium cation.

Synthesis of 1,8-dioxo-octahydroacridines by the reaction of 5,5-dimethyl-1,3-cyclohexanedione, aromatic aldehydes, and NH₄OAc in the ionic liquid [BMIm][BF₄]-0.5 mol% Mg(BF₄)₂ at 80 °C.



Product ^a	Ar	Time (min)	Yield (%) ^b
9a	C ₆ H ₅	15	82
9b	$2-ClC_6H_4$	15	98
9c	4-ClC ₆ H ₄	15	95
9d	3-NO ₂ C ₆ H ₄	15	98
9e	$4-NO_2C_6H_4$	30	85
9f	4-BrC ₆ H ₄	30	78
9g	4-HOC ₆ H ₄	15	96
9h	$4-H_3CC_6H_4$	30	81
9i	$4-H_3COC_6H_4$	30	82
9j	$4-N(CH_3)_2C_6H_4$	30	80

^a Isolated yield.
^b Refs. [33–38].

Table 5

The effect of [BMIm][BF₄]-0.5 mol% Mg(BF₄)₂ recycling on the xanthene yield.

Run	Cycle	Yield (%) ^a
1	Fresh	86
2	1	85
3	2	85
4	3	84
5	4	83

Reaction conditions: 5,5-dimethyl-1,3-cyclohexanedione 1, 2.0 mmol; 4-chlorobenzaldehyde 2c, 1.0 mmol; 1 mL of $[BMIm][BF_4]$ –0.5 mol% $Mg(BF_4)_2$ at 80 $^\circ C$.

^a Isolated yields.

3.1. Synthesis of the ionic liquid $[Bmim][BF_4] - 0.5 mol\% Mg(BF_4)_2$

1-Methylimidazole (5.1 g, 62.1 mmol) was added to 32 mL of 1chlorobutane. The mixture was heated to reflux for 24 h and then cooled to room temperature. The obtained oily product was separated from reaction mixture by decanting and washed with EtOAc $(2 \times 20 \text{ mL})$. Solvent of the collected organic phase was removed under reduced pressure to give 1-butyl-3-methylimidazolium chloride ([BMIm]Cl). In second step, to a solution of [BMIm]Cl (7.0 g, 40.1 mmol) and MgCl₂ (1.0 g, 10.5 mmol) diluted with dry acetone (50 mL) was added NaBF₄ (8.7 g, 79.2 mmol). The mixture was stirred for 48 h at room temperature to get a solution and then to afford precipitation of NaCl. After separation of the precipitates (mainly NaCl associated with excess Mg^{2+} salts) the solvent of the filtered solution was removed under reduced pressure whereupon the ionic liquid [BMIm] BF_4 doped with $Mg(BF_4)_2$ was obtained as a yellow oil. Atomic absorption analysis of the obtained ionic liquid has revealed a concentration of 0.6 mg/mL of Mg²⁺ being equal to $0.5 \text{ mol}\% \text{ of Mg}^{2+}$ in the ionic liquid.

3.2. General procedure for preparation of 1,8-dioxo-octahydroxanthenes and 14-aryl-14H-dibenzo[a,j]xanthene derivatives

To a mixture of an aromatic aldehyde (1 mmol) and 5,5dimethyl-1,3-cyclohexanedione or 2-naphthol (2 mmol) in a round bottom flask was added 1 mL of [BMIm][BF4]–0.5 mol% Mg(BF4)₂. The mixture was heated at 80 °C and the reaction was monitored by TLC using silica gel coated on aluminum sheets and ethyl acetate-petroleum ether as eluent. After completion of the reaction, water (8 mL) was added to the mixture and filtered. The solid residue was recrystallized from ethanol 95.5%.

3.3. General procedure for the synthesis of

1,8-dioxo-decahydroacridine derivatives

Ammonium acetate (0.09 g, 1.2 mmol) was added to the solution of an aromatic aldehyde (1 mmol) and 5,5-dimethyl-1,3-cyclohexanedione (0.28 g, 2 mmol) in 1 mL of [BMIm]BF₄-0.5 mol% Mg(BF₄)₂. The reaction was conducted under the conditions mentioned above. After completion of the reaction, water (8 mL) was added to the mixture and filtered. The solid residue was recrystallized from ethanol 95.5%.

4. Conclusion

An enhanced catalytic activity was observed for the magnesium salt of a less coordinative anion, $Mg(BF_4)_2$, dissolved in the ionic liquid [BMIm]BF₄. Based on this finding, the ionic liquid [BMIm]BF₄ doped with 0.5 mol% $Mg(BF_4)_2$ was prepared and employed in development of an expedient method

for the synthesis of 1,8-dioxo-octahydroxanthenes, 14-aryl-14*H*-dibenzo[*a*,*j*]xanthenes, and 1,8-dioxo-decahydroacridines. The ionic liquid system tolerates the presence of various functional groups on the aldehydes used in this investigation and have the advantages of being inexpensive, easily available, and reusable. It is a dilute homogeneous metal catalyst having the capacity to dissolve the reactants and tolerating air and moisture due to stability of its ionic constituents. Application of this catalyst offered a simple, clean, and cost effective method for the synthesis of the title compounds. It is important to note that in the absence of the ionic liquid, the yields of reactions were traced even at 80 °C and longer reaction time.

Acknowledgment

We gratefully acknowledge the financial support from the Research Council of University of Guilan.

References

- [1] S.L. Chen, S.-J. Ji, T.-P. Loh, Tetrahedron Lett. 44 (2003) 2405.
- [2] Z. Li, C. Wei, L. Chen, R.S. Varma, C.J. Li, Tetrahedron Lett. 45 (2004) 2443.
- [3] R. Skoda-Foldes, E. Takacs, J. Horvath, Z. Tuba, L. Kollar, Green Chem. 5 (2003) 643.
- [4] Y. Li, H. Alper, Z. Yu, Org. Lett. 8 (2006) 5199.
- [5] V. Conte, E. Elakkari, B. Floris, V. Mirruzzo, P. Tagliatesta, Chem. Commun. (2005) 1587.
- [6] H. Ambrogio, A. Arcadi, S. Cacchi, G. Fabrizi, F. Marinelli, Synlett (2007) 1775.
- [7] X. Zhang, X. Fan, H. Niu, J. Wang, Green Chem. 5 (2003) 267.
- [8] A. Shestopalov, L. Rodinovskaya, A. Shestopalov, S. Zlotin, V. Nesterov, Synlett (2003) 2309.
- [9] K. Rad-Moghadam, M. Sharifi-Kiasaraie, Tetrahedron 65 (2009) 8816.
- [10] K. Rad-Moghadam, M. Sharifi-Kiasaraie, H. Taheri-Amlashi, Tetrahedron 66 (2010) 2316.
- [11] K. Rad-Moghadam, L. Youseftabar-Miri, J. Fluorine Chem. 135 (2012) 213.
- [12] K. Rad-Moghadam, L. Youseftabar-Miri, Tetrahedron 67 (2011) 5693.
- [13] H.K. Wang, S.L. Morris-Natschke, K.H. Lee, Med. Res. Rev. 17 (1997) 367.
 [14] A.V. Rukavishnikov, M.P. Smith, G.B. Birrell, J.F.W. Keana, O.H. Griffith, Tetra-
- hedron Lett. 39 (1998) 6637.
- [15] S. Hatakeyma, N. Ochi, H. Numata, S. Takano, J. Chem. Soc., Chem. Commun. (1988) 1202.
- [16] C.N. O'Callaghan, T.B.H. McMurry, J. Chem. Res. (1995) 214.
- [17] A.R. Khosropour, M.M. Khodaei, H. Moghannian, Synlett (2005) 955.
- [18] T.S. Jin, J.S. Zhang, J.C. Xiao, A.Q. Wang, T.S. Li, Synlett (2004) 866.
- [19] X.S. Wang, D.Q. Shi, Y.L. Li, H. Chen, X.Y. Wei, Z.M. Zong, Synth. Commun. 35 (2005) 97.
- [20] F. Darvish, S. Balalaei, F. Chadegani, P. Salehi, Synth. Commun. 37 (2007) 1059.
- [21] T.S. Jin, J.S. Zhang, A.Q. Wang, T.S. Li, Ultrason. Sonochem. 13 (2006) 220.
- [22] X. Fan, X. Hu, X. Zhang, J. Wang, Can. J. Chem. 83 (2005) 16.
- [23] G. Song, B. Wang, H. Luo, L. Yang, Catal. Commun. 8 (2007) 673.
- [24] B. Das, P. Thirupathi, I. Mahender, K.R. Reddy, B. Ravikanth, L. Nagarapu, Catal. Commun. 8 (2007) 535.
- [25] B. Das, P. Thirupathi, I. Mahender, V.S. Reddy, Y.K. Rao, J. Mol. Catal. A: Chem. 247 (2006) 233.
- [26] R. Kumar, G.C. Nandi, R.K. Verma, M.S. Singh, Tetrahedron Lett. 51 (2010) 442.
- [27] M. Dabiri, S.C. Azimi, A. Bazgir, Chem. Pap. 62 (2005) 522.
- [28] M. Seyyedhamzeh, P. Mirzaei, A. Bazgir, Dyes Pigments 76 (2008) 836.
- [29] R. Shan, C. Velazquez, E. Knaus, J. Med. Chem. 47 (2004) 254.
- [30] D.M. Stout, A.I. Meyers, Chem. Rev. 82 (1982) 223.
- [31] R.A. Janis, D.J. Triggle, J. Med. Chem. 26 (1983) 775
- [32] P. Shanmugasundaram, P. Murugan, V.T. Ramakrishnan, N. Srividya, P. Ramamurthy, Heteroat. Chem. 7 (1996) 17.
- [33] S. Tu, C. Miao, Y. Gao, F. Fang, Q. Zhuang, Y. Feng, D. Shi, Synlett (2004) 255.
- [34] P. Murugan, P. Shanmugasundaram, V.T. Ramakrishnan, B. Venkatachalapathy, N. Srividya, P. Ramamurthy, K. Gunasekaran, D. Velmurugan, J. Chem. Soc. Perkin Trans. 24 (1998) 999.
- [35] S.J. Tu, Z. Lu, D. Shi, C. Yao, Y. Gao, C. Guo, Synth. Commun. 32 (2002) 2181.
- [36] G.W. Wang, C.B. Miao, Green Chem. 8 (2006) 1080.
- [37] S.M. Vahdat, M. Akbari, Orient. J. Chem. 27 (2011) 1573.
- [38] A. Davoodnia, A. Khojastehnezhad, N. Tavakoli-Hoseini, Bull. Korean Chem. Soc. 32 (2011) 2243.
- [39] S.K. Tyrlik, D. Szerszen, M. Olejnik, W. Danikiewicz, J. Mol. Catal. A: Chem. 106 (1996) 223.
- [40] K. Asit, S. Chakraborti, J. Org. Chem. 71 (2006) 5785.
- [41] M. Hatano, T. Horibe, K. Ishihara, Org. Lett. 12 (2010) 3502.