Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lsyc20

$CeCl_3 \cdot 7H_2O$-Catalyzed One-Pot Synthesis of Hantzsch 1,4-Dihydropyridines at Room Temperature

Gowravaram Sabitha [a], K. Arundhathi [a], K. Sudhakar [a], B. S. Sastry [b] & J. S. Yadav [a]
[a] Organic Division I, Indian Institute of Chemical Technology, Hyderabad, India
[b] University College of Pharmaceutical Sciences, Andhra University, Vizag, India
Published online: 14 Jul 2009.

To cite this article: Gowravaram Sabitha, K. Arundhathi, K. Sudhakar, B. S. Sastry & J. S. Yadav (2009) $CeCl_3 \cdot 7H_2O$-Catalyzed One-Pot Synthesis of Hantzsch 1,4-Dihydropyridines at Room Temperature, Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry, 39:16, 2843-2851, DOI: 10.1080/00397910802656091

To link to this article: http://dx.doi.org/10.1080/00397910802656091

Synthetic Communications®, 39: 2843–2851, 2009

ISSN: 0039-7911 print/1532-2432 online
DOI: 10.1080/00397910802656091

Taylor & Francis
Taylor & Francis Group

$CeCl_3 \cdot 7H_2O$-Catalyzed One-Pot Synthesis of Hantzsch 1,4-Dihydropyridines at Room Temperature

Gowravaram Sabitha,[1] K. Arundhathi,[1] K. Sudhakar,[1] B. S. Sastry,[2] and J. S. Yadav[1]

[1]Organic Division I, Indian Institute of Chemical Technology, Hyderabad, India
[2]University College of Pharmaceutical Sciences, Andhra University, Vizag, India

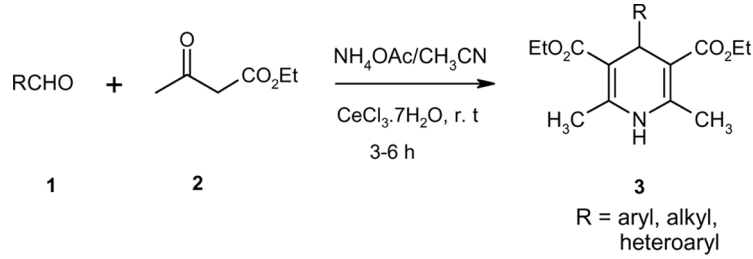
Abstract: An efficient synthesis of a series of 1,4-dihydropyridines was accomplished at room temperature by the reaction of aldehydes with ammonium acetate and ethyl acetoacetate catalyzed by $CeCl_3 \cdot 7H_2O$.

Keywords: $CeCl_3 \cdot 7H_2O$, 1,4-dihydropyridines, multicomponent reactions (MCRs), room temperature

INTRODUCTION

Hantzsch 1,4-dihydropyridines (1,4-DHPs) are the most important class of calcium-channel modulators[1] and have been introduced as potential drugs for the treatment of congestive heart failure.[2] Some of them, such as nifedipine,[3] amlodipine, isradipine, and nimodipine, have been commercialized and are known as vital drugs in the treatment of angina and hypertension[4] because of their vasodilator properties. The DHP scaffold is common in many vasodialator, bronchiodialator, antitumor, hepatoprotective, and antidiabetic agents.[5] 1,4-DHPs also exhibit several

Received October 18, 2008.
Address correspondence to Gowravaram Sabitha, Organic Division I, Indian Institute of Chemical Technology, Hyderabad 500 007, India. E-mail: gowravar amsr@yahoo.com



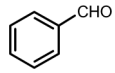
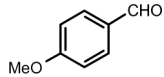
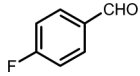
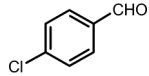
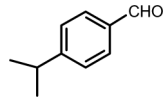
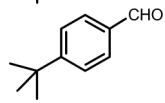
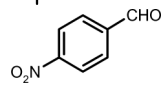
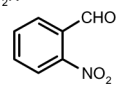
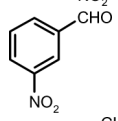
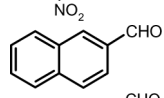
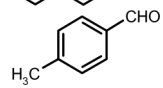
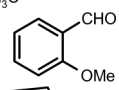
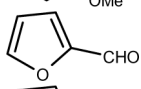
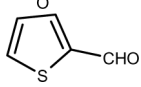
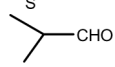
Scheme 1.

medicinal applications, which include neuroprotectant[6a] and platelet anti-aggregatory activity,[6b] and are important in Alzheimer's disease as anti-ischemic agents. The success of those calcium antagonists has led to the development of novel synthetic strategies to improve their classical methods of preparation.[7] The first 1,4-DHPs were obtained more than one century ago by Hantzsch.[5] This reaction involves heating a mixture of an aldehyde, an ethyl or methyl acetoacetate, and ammonia either in acetic acid or ethanol for a long time, producing poor yields. Modified procedures involve the use of preformed Knoevenagel adducts between the aldehyde and the ketoester or the use of preformed enaminoesters. Recently, numerous modified methods under improved conditions have been reported.[9] In addition to this, some procedures require the use of an autoclave and microwave irradiation. However, many of them suffer from drawbacks such as unsatisfactory yields, high temperatures, and long reaction times. Pharmacological profiles of Hantzsch 1,4-DHPs still attract much attention, and further development of mild and simple methods for the synthesis of these compounds is in great demand. To the best of our knowledge, the synthesis of 1,4-DHP derivatives has not reported using $CeCl_3 \cdot 7H_2O$.

In continuation of our interest in the application of $CeCl_3 \cdot 7H_2O$ for development of useful synthetic methodologies, we report a simple, mild, and efficient method for the preparation of 1,4-DHPs and their derivatives at room temperature using $CeCl_3 \cdot 7H_2O$ as a cost-effective and water-tolerant catalyst.

Thus, the reaction of 1 eq. of benzaldehyde **1a** and 2 eq. of ethyl acetoacetate **2a** with 1.5 eq. of ammonium acetate in the presence of a catalytic amount of $CeCl_3 \cdot 7H_2O$ in acetonitrile at room temperature for 3 h resulted in 1,4-dihydropyridine **3a** in 80% yield (Scheme 1). Encouraged by this result, a wide range of aromatic aldehydes were used for this conversion. As indicated in Table 1, in all cases the reaction proceeds efficiently at room temperature using a catalytic amount of catalyst, giving

Table 1. $CeCl_3 \cdot 7H_2O$-catalyzed synthesis of Hantzsch 1,4-dihydropyridines

Entry	Aldehyde	Time (h)	Yield (%)	Mp (°C)
3a		3	80	158
3b		4	82	159
3c		3.5	86	139
3d		4	91	144
3e		5	81	97
3f		5	86	95
3g		3.5	82	128–129
3h		5.6	65	169
3i		5	71	163
3j		5	72	196
3k		3	82	115
3l		6	61	142
3m		5.5	92	164–165
3n		5	94	156–159
3o		5	89	95–98

[a]All products were characterized by spectral data and compared with the authentic samples.

[b]Isolated pure products.

very good yields of products in 3–6 h. From Table 1, one can see that both aromatic aldehydes with an electron-withdrawing group and those with an electron-donating group can be employed in the synthesis of Hantzsch esters. Aliphatic and heterocyclic aldehydes also reacted well at room temperature to furnish the corresponding Hantzsch DHPs in good yields. The synthesized Hantzsch esters are known compounds, and their identities were confirmed by comparison of their spectral data and melting points with those reported in the literature. The experimental procedure is simple and mild and has the ability to tolerate a variety of functional groups such as methoxy, nitro, hydroxy, and halides under the reaction conditions. The advantages of the process are increased reactivity at room temperature, associated with low cost, availability, and easy handling of the catalyst.

In summary, we have demonstrated a simple, efficient, and green protocol for the one-pot synthesis of 1,4-DHPs by treatment of ethyl acetoacetate and aldehydes with NH_4OAc using $CeCl_3{\cdot}7H_2O$ as a catalyst at room temperature. The simple workup, easy isolation of products, good yields, mild reaction conditions, short reaction times, and nontoxic catalyst are the salient features of this new procedure.

EXPERIMENTAL

Melting points were determined using a Buchi R-535 apparatus and are uncorrected. All reactions were monitored by thin-layer chromatography (TLC) using silica-coated plates and visualization under ultraviolet (UV) light. Yields refer to pure products isolated by spectroscopically (^{1}H, IR) homogeneous material. ^{1}H NMR spectra were recorded on Varian FT 200-MHz (Gemini) and Bruker UXNMR FT 300-MHz (Avance) instruments in $CDCl_3$. Chemical shift values were reported in parts per million (δ) relative to tetramethylsilane (TMS) (δ 0.0) as an internal standard. Mass spectra(MS) were recorded under electron impact at 70 eV on an LC-MSD instrument (Agilent Technologies).

General Procedure

A mixture of aldehyde (1 mmol), ethyl acetoacetate (2 mmol), NH_4OAc (1.5 mmol), and $CeCl_3{\cdot}7H_2O$ (0.1 mmol) was stirred at room temperatue in acetonitrile for an appropriate time (Table 1). After completion of the reaction mixture as indicated by TLC, acetonitrile was removed, and ethyl acetate was added to the residue. Ethyl acetate was washed with water and brine solution, dried, and concentrated. The crude residue was purified by column chromatography (EtOAc/hexane, 1:3) to afford

the pure product. The structure of the products was confirmed by spectral data (^{1}H NMR, IR, mass).

Spectral Data

Compound **3a**

Mp 158°C; IR (KBr): 3355, 2980, 1682, 1504, 855, 677 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): 0.95 (t, $J = 8.32$ Hz, 6H), 2.31 (s, 6H), 4.06 (q, $J = 8.32$ Hz, 4H), 4.61 (s, 1H), 5.63 (brs, 1H), 7.06–7.21 (m, 5H); ESI MS: m/z 329 (M^+).

Compound **3b**

Mp 159°C; IR (KBr): 3342, 2923, 2856, 1692, 1649, 1493, 831, 746, 680, 592 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): 1.06 (t, $J = 7.5$ Hz, 6H), 2.34 (s, 6H), 3.78 (s, 3H), 4.01 (q, $J = 8.32$ Hz, 4H), 4.81 (s, 1H), 5.41 (brs, 1H), 7.16 (m, 4H); ESI MS: m/z 360 ($M^+ + 1$).

Compound **3c**

Mp 139°C; IR (KBr): 3337, 2980, 2930, 1682, 1504, 855, 753, 677 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$): 1.91–2.78 (m, 12H, $6CH_2$), 4.50 (s, 1H, CH), 6.93 (d, $J = 8.4$ Hz, 1H, ArH), 7.20 (d, $J = 2.4$ Hz, 1H, ArH), 7.32 (dd, $J = 8.4$ Hz, $J = 2.4$ Hz, 1H, ArH), 10.71 (s, 1H, OH); ESI MS: m/z 347 (M^+).

Compound **3d**

Mp 144°C: IR (KBr): 3337, 2926, 2830, 1682, 1487, 855, 753, 677 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$): 1.2 (t, $J = 7.5$ Hz, 6H), 2.60 (s, 6H), 4.12 (q, $J = 8.2$ Hz, 4H), 4.68 (s, 1H), 5.78 (brs, 1H), 7.20–7.25 (m, 2H), 7.41 (d, $J = 9.06$ Hz, 1H), 7.51 (d, $J = 8.3$ Hz, 1H); ESI MS: m/z 386 ($M^+ + Na$).

Compound **3e**

Mp 97°C: IR (KBr): 3355, 2926, 2856, 1702, 1682, 1484, 856, 681 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): 1.31 (t, $J = 8.2$ Hz, 6H), 1.41 (s, 6H), 2.32 (s, 6H), 2.60 (s, 6H), 2.89 (m, 1H), 4.12 (q, $J = 8.4$ Hz, 4H), 4.68

(s, 1H), 5.81 (brs, 1H), 7.01 (d, $J = 8.36$ Hz, 2H), 7.21 (d, $J = 8.3$ Hz, 2H); ESI MS: m/z 291 (M^+).

Compound **3f**

Mp 95°C; IR (KBr): 3340, 2962, 2869, 1727, 1695, 1487, 680, 556 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): 1.01 (s, 1H), 1.12 (s, 3H), 1.21 (t, $J = 8.2$ Hz, 6H), 2.31 (s, 6H), 4.01 (q, $J = 8.4$ Hz, 4H), 4.67 (s, 1H), 5.71 (brs, 1H), 7.01–7.20 (m, 3H), 7.41–7.50 (m, 1H); ESI MS: m/z 385 (M^+).

Compound **3g**

Mp 128–129°C; IR (KBr): 3322, 2927, 2856, 1702, 1647, 1486, 859, 753, 601 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): 0.95 (t, $J = 8.2$ Hz, 6H), 2.34 (s, 6H), 4.07 (q, $J = 8.4$ Hz, 4H), 4.72 (s, 1H), 5.76 (brs, 1H), 7.41 (d, $J = 8.56$ Hz, 2H), 8.10 (d, $J = 8.56$ Hz, 2H); ESI MS: m/z 374 (M^+).

Compound **3h**

Mp 169°C; IR (KBr): 3355, 2926, 2855, 1659, 1485, 847, 756, 620, 585 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): 1.01 (t, $J = 8.3$ Hz, 6H), 2.41 (s, 6H), 4.12 (q, $J = 8.4$ Hz, 4H), 4.68 (s, 1H), 5.79 (brs, 1H), 7.12–7.25 (m, 4H); ESI MS: m/z 374 (M^+).

Compound **3i**

Mp 178°C; IR (KBr): 3358, 2925, 2854, 1646, 1484, 808, 663 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): 0.98 (t, $J = 8.3$ Hz, 6H), 2.31 (s, 6H), 4.06 (q, $J = 8.4$ Hz, 4H), 4.67 (s, 1H), 5.79 (brs, 1H), 6.98–7.21 (m, 4H); ESI MS: m/z 374 (M^+).

Compound **3j**

Mp 199°C; IR (KBr): 3342, 2978, 2929, 1725, 1692, 1488, 860, 756 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): 0.96 (t, $J = 8.2$ Hz, 6H), 2.30 (s, 6H), 4.01 (q, $J = 8.4$ Hz, 4H), 5.61 (brs, 1H), 5.72 (s, 1H), 7.21–7.45 (m, 4H), 7.51 (d, $J = 8.6$ Hz, 1H), 7.62 (d, $J = 8.6$ Hz, 1H), 8.12 (d, $J = 8.6$ Hz, 1H); ESI MS: m/z 380 (M^+).

Compound **3k**

Mp 115°C; IR (KBr): 3358, 2925, 1696, 1651, 1487, 849, 786, 610 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): 1.21 (t, $J = 8.3$ Hz, 6H), 2.01 (s, 1H), 2.41 (s, 6H), 4.04 (q, $J = 8.4$ Hz, 4H), 5.34 (s, 1H), 5.78 (brs, 1H), 6.99 (d, $J = 8.08$ Hz, 2H), 7.16 (d, $J = 7.3$ Hz, 2H); ESI MS: m/z 344 ($M^+ + 1$).

Compound **3l**

Mp 142°C; IR (KBr): 3342, 2923, 2856, 1692, 1649, 1493, 831, 784, 680 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): 0.98 (t, $J = 8.3$ Hz, 6H), 2.29 (s, 6H), 3.78 (s, 3H), 3.99 (q, $J = 8.4$ Hz, 4H), 4.78 (s, 1H), 5.71 (brs, 1H), 7.16–7.23 (m, 4H); ESI MS: m/z 409 ($M^+ + 1$).

Compound **3m**

Mp 164°C; IR (KBr): 3350, 2981, 1682, 1503, 860, 756 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): 1.26 (t, $J = 8.2$ Hz, 6H), 2.31 (s, 6H), 4.26 (q, $J = 8.2$ Hz, 4H), 4.96 (s, 1H), 5.63 (brs, 1H), 6.93–7.12 (m, 3H); ESI MS: m/z 319 ($M^+ - 1$).

Compound **3n**

Mp 156–159°C; IR (KBr): 3340, 2980, 1652, 1486 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): 1.29 (t, $J = 8.8$ Hz, 6H), 2.21 (s, 6H), 4.10–4.26 (q, $J = 8.0$ Hz, 4H), 5.30 (brs, 1H), 5.93 (brs, 1H), 6.73 (brs, 1H), 6.78 (t, $J = 8.8$ Hz, 1H), 7.0 (d, $J = 8.8$ Hz, 1H); ESI MS: m/z 334 (M^+).

Compound **3o**

Mp 96°C; IR (KBr): 3358, 2952, 1681, 1515 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): 0.93 (d, $J = 7.2$ Hz, 6H), 1.23 (t, $J = 8.2$ Hz, 6H), 1.51 (m, 1H), 2.31 (s, 6H), 3.92 (d, $J = 7.2$ Hz, 1H), 4.17 (q, $J = 8.2$ Hz, 4H), 5.69 (brs, 1H); ESI MS: m/z 296 ($M^+ + 1$).

ACKNOWLEDGMENT

K. S. thanks the University Grants Commission, New Delhi, for the award of a fellowship.

REFERENCES

1. (a) Bossert, F.; Meyer, H.; Wehinger, E. Microwave activation in the chemistry of Hantzsch 1,4-dihydropyridines. *Angew. Chem., Inter. Ed. Engl.* **1981**, *20*, 762; (b) Nakayama, H.; Kasoaka, Y. Chemical identification of binding sites for calcium channel antagonists. *Heterocycles* **1996**, *42*, 901.
2. (a) Sunkel, C. E.; Santos, L.; Garcia, A. G. Synthesis of 3-[(2,3-dihydro-1, 1,3-trioxo-1,2-benzisothiazol-2-yl)alkyl] 1,4-dihydropyridine-3,5-dicarboxylate derivatives as calcium channel modulators. *J. Med. Chem.* **1992**, *35*, 2407; (b) Vo, D.; Matome, W. C.; Ramesh, M. Syntheses, calcium channel agonist–antagonist modulation activities, and voltage-clamp studies of isopropyl 1,4-dihydro-2,6-dimethyl-3-nitro-4-pyridinylpyridine-5-carboxylate racemates and enantiomers. *J. Med. Chem.* **1995**, *38*, 2851.
3. Gaudio, A. C.; Korolkovas, A.; Takahata, Y. Quantitative structure–activity relationships for 1,4-dihydropyridine calcium channel antagonists (nifedipine analogues): A quantum chemical/classical approach. *J. Pharm. Sci.* **1994**, *83*, 1110.
4. (a) Klusa, V. Cerebrocrast neuroprotectant cognition enhancer. *Drugs. Fut.* **1995**, *20*, 135; (b) Bretzel, R. G.; Bollen, C. C.; Maeser, E.; Federlin, K. F. Trombodipine platelet aggregation inhibitor antithrombotic. *Drugs. Fut.* **1992**, *17* (6), 465; (c) Gordeev, M. F.; Patel, D.; Gordon, E. M. Approaches to combinatorial synthesis of heterocycles: A solid-phase synthesis of 1,4-dihydropyridines. *J. Org. Chem.* **1996**, *61*, 924; (d) Brietenbucher, J. G. Solid-phase synthesis of 4-aryl-1,4-dihydropyridines via the Hantzsch three-component condensation. *Tetrahedron Lett.* **2000**, *41*, 4311.
5. Hantzsch, J. Hantzsch dihydropyridine synthesis. *Liebigs Ann. Chem.* **1882**, *215*, 1.
6. (a) Litvic, M.; Cepanec, I.; Vinkovic, V. A convenient Hantzsch synthesis of 1,4-dihydropyridines using tetraethyl orthosilicate. *Heterocycl. Commun.* **2003**, *9* (4), 385; (b) Muchintala, M.; Vidavalur, S.; Yerra, K. R.; Tzeng, Y.-M.; Chenchugari, S. A simple and efficient one-pot synthesis of 1,4-dihydropyridines using heterogeneous catalyst under solvent-free conditions. *J. Mol. Cat. A: Chem.* **2006**, *260*, 179; (c) Zolfigol, M. A.; Safaiee, M. Synthesis of 1,4-dihydropyridines under solvent-free conditions. *Synlett* **2004**, *5*, 827; (d) Grazia, M.; Avallone, L.; Zanarone, S.; Abignente, E.; Mangoni, A. Research on heterocyclic compounds, XLIII: Synthetic studies on 1,4-dihydropyridine derivatives. *J. Hetercycl. Chem.* **2002**, *39*, 1117; (e) Wang, G. W.; Xia, J. J.; Miao, C. B. Environmentally friendly and efficient synthesis of various 1,4-dihydropyridines in pure water. *Bull. Chem. Soc. J.* **2006**, *79* (3), 454; (f) Breitenbucher, J. G.; Figliozzi, G. Solid-phase synthesis of 4-aryl-1,4-dihydropyridines via the Hantzsch three-component condensation. *Tetrahedron Lett.* **2000**, *41*, 4311; (g) Ohberg, L.; Westmann, J. An efficient and fast procedure for the Hantzsch dihydropyridine synthesis under microwave conditions. *Synlett* **2001**, 1296; (h) Anniyappan, M.; Muralidharan, D.; Perumal, P.T. Synthesis of Hantzsch 1,4-dihydropyridines under microwave irradiation. *Synth. Commun.* **2002**, *32*, 659; (i) Lavilla, R. Recent developments in the chemistry of dihydropyridines. *J. Chem. Soc., Perkin Trans. 1*

2002, *9*, 1141; (j) Rodriguez, H.; Reyes, O.; Suarez, M.; Garay, E.; Perez, R.; Cruz, J.; Verdecia, Y.; Martin, N.; Seoane, C. Solid-phase synthesis of 4-aryl substituted 5-carboxy-6-methyl-3,4-dihydropyridones. *Tetrahedron Lett.* **2002**, *43*, 439; (k) Correa, W. H.; Scott, L. Solvent-free, two-step synthesis of some unsymmetrical 4-aryl-1,4-dihydropyridines. *Green Chem.* **2001**, *3*, 296.

7. Watanabe, Y.; Shiota, K.; Hoshiko, T.; Ozaki, S. An efficient procedure for the Hantzsch dihydropyridine. *Synthesis* **1983**, 761.
8. (a) Alajarin, R.; Vaquero, J. J.; Navio, J. L. G.; Alvarez Builla, J. Synthesis of 1,4-dihydropyridines under microwave irradiation. *Synlett* **1992**, 297; (b) Ohberg, L.; Westman, J. An efficient and fast procedure for the Hantzsch dihydropyridine synthesis under microwave conditions. *Synlett* **2001**, 1296.
9. (a) Sabitha, G.; Yadav, J. S. Cerium(III) chloride in organic synthesis. In *Encyclopedia of Reagents for Organic Synthesis*; L. A. Paquette, (Ed.); Wiley-VCH: Weinheim, 2006; (b) Satheesh Babu, R. Spotlight on cerium (III) chloride hepta hydrate. *Synlett* **2002**, *11*, 1935; (c) Sabitha, G.; Babu, R. S.; Rajkumar, M.; Yadav, J. S. Cerium(III) chloride promoted highly regioselective ring opening of epoxides and aziridines using NaN_3 in acetonitrile: A facile synthesis of 1,2-azidoalcohols and 1,2-azidoamines. *Org. Lett.* **2002**, *4* (3), 343; (d) Yadav, J. S.; Reddy, B. V. S.; Reddy, M. S.; Sabitha, G. A facile cleavage of ketone N,N-dimethylhydrazones by $CeCl_3{\cdot}7H_2O$-SiO_2. *Synlett* **2001**, *7*, 1134; (e) Sabitha, G.; Babu, R. S.; Rajkumar, M.; Srividya, R.; Yadav, J. S. A highly efficient, mild, and selective cleavage of β-methoxyethoxymethyl (MEM) ethers by cerium(III) chloride in acetonitrile. *Org. Lett.* **2001**, *3* (8), 1149; (f) Sabitha, G.; Babu, R. S.; Rajkumar, M.; Reddy, C. S.; Yadav, J. S. Highly regioselective ring opening of epoxides and aziridines using cerium(III) chloride. *Tetrahedron Lett.* **2001**, *42*, 3955; (g) Sabitha, G.; Rama Subba Rao, V.; Sudhakar, K.; Raj Kumar, M.; Venkat Reddy, E.; Yadav, J. S. Study of conventional versus microwave-assisted reactions of 3,4-epoxy alcohols by $CeCl_3{\cdot}7H_2O$: Synthesis of tetrahydrofurans and 1-chloro-3-substituted-2-propanols. *J. Mol. Cat. A: Chem.* **2008**, *280*, 16.