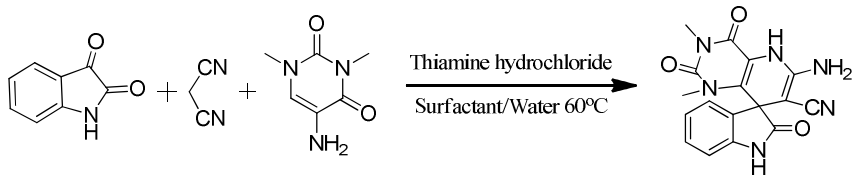
Heterocyclic Letters
Vol. 7| No.4|959-966|Aug-Oct|2017
ISSN : (print) 2231–3087 / (online) 2230-9632
CODEN: HLEEAI
http://heteroletters.org

THIAMINE HYDROCHLORIDE AS A PROMOTER FOR THE EFFICIENT AND GREEN SYNTHESIS OF SPIROOXINDOLES AND ITS DERIVATIVES IN AQUEOUS MICELLAR MEDIUM

Akhilesh Kumar

Department of Chemistry, University of Allahabad, Allahabad-211002 (India);
E-mail: aks.modanwal@gmail.com

Abstract: An efficient, one pot Thiamine hydrochloride promoted synthesis of spirooxindoles and its derivatives in aqueous micellar medium has been reported. The important aspects of the present methodology is environmentally benign reaction conditions, operational simplicity, cost effectiveness, short reaction times, easily recoverable and reusable catalyst, high yields, 100% atom economy.
Keywords: Thiamine hydrochloride, Environmentally benign, spirooxindoles, aqueous micellar medium.



Introduction

Multicomponent reactions (MCRs) have emerged as a powerful new strategy in synthetic organic chemistry and drug discovery. MCRs are a precise synthetic tool to access products with structural complexity and diversity in a single operation with improved atom and time economy, simplicity, synthetic efficiency and lower number of reactions and purification steps.[i] The spirooxindole system is the core structure of many pharmacological agents and natural alkaloids.[ii-v] For example, spirotryprostatin B, a natural alkaloid isolated from the fermentation broth of *Aspergillus fumigatus*, has been identified as a novel inhibitor of microtubule assembly,[iii] and pteropodine and isopteropodine have been shown to modulate the function of muscarinic serotonin receptors[v].The heterocyclic spirooxindole ring is a core structure presenting in a number of pharmaceuticals and natural products,[vi] including cytostatic alkaloids such as spirotryprostatins A, B, and strychnophylline.[vii] The unique structural array and the highly pronounced pharmacological activity displayed by the class of spirooxindole compounds have made them attractive synthetic targets.[viii] The compounds with spirooxindole ring system are attracting considerable interest as antimicrobial and antitumor agents, and as inhibitors of the human NKI receptor, as well as being found in a

number of alkaloids like spirotryprostatin, (þ)-elacomine, and horsifiline (Scheme 1).[ix] The conformational restriction associated to the structural rigidity significantly affects their biological activity.[x] For the synthesis and structural modification of the biologically active spiro compounds[xi-xiv], Spiro-2-oxindole especially spiro fused to other cyclic structures (Fig.1) is subject of tremendous interest in synthetic organic chemistry and medicinal chemistry due to its fascinating medicinal properties such as anti-HIV[xv], anticancer[xvi], antitubercular[xvii], antimalarial[xviii], progesterone receptor modulator[xix] and NMDM2 inhibitor[xx]. Architecture of spiro compounds due to their N steric strain has been a challenge for synthetic organic chemists and recently several attempts have also been made for the formation of spirooxindoles via one pot multicomponent in literature[xxi]. Although all reports have their own merits, continuing researches to find green and economical methods under catalyst free condition seem necessary. Spirooxindole is an important heterocyclic moiety, present as a key structural motif in a variety of alkaloids and biologically active molecules.[xxii-xxiii] Though a large number of methods for the synthesis of spirooxindoles have been reported till date, Song-Lei Zhu, et al. synthesise of spirooxindoles from Isatin Malanonitrile and 1,3-cyclohexanedione, hydroxy coumarin or barbituric acid/2-thiobarbituric acid in water using TEBA at 60^{o}C[xxiv] Gnanamani Shanthi et al. of spirooxindoles from Isatin Malanonitrile and naphthol by using $InCl_3$/ SiO_2/ MW (or) $InCl_3$/ CH_3CN Reflux[xxv] Li-Min Wang et al. synthesis of spirooxindoles from Isatin, Malanonitrile and different 1,3-diketones in water using Sodium Stearate at 60^{o}C[xxvi] Shailesh P. Satasia et al. Synthesis of spirooxindoles from Isatin, Malanonitrile and different 1,3-diketones in water using HIL in ethanol at room temperature[xxvii] yet the development of more efficient routes for accessing to access existing class as well as novel spirooxindole derivatives remains an exigent task for organic chemists.[xxiia,xxviii,xxix] Recently, spirooxindoles derivatives have been reported as exhibiting very good anti-cancer activity.[xxxii]

The use of different organic catalysts has achieved spacious interest in organic synthesis due to their several reward such as simple work up procedure, environmentally benign procedure, recyclability, low price[xxxi]. In this view, thiamine hydrochloride (VB_1; Fig.1) analogs, serve as potent catalysts and have been found to be useful in various organic synthesis.[xxxii,xxxiii] With the improvement of modern synthetic approaches, it has been extensively accepted that there is a emergent need for the development of green, environmentally benign procedure in the organic synthesis.[xxxiv, xxxv]

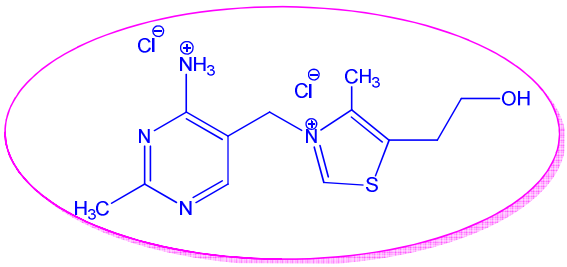
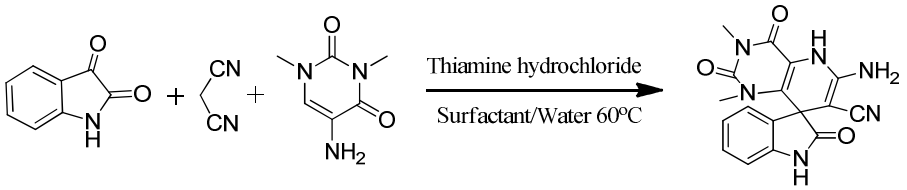


Fig 1: Structure of thiamine-hydrochloride (VB_1)

Even though a numerous methodology have been reported under improved conditions but unfortunately many of them suffer from one or more drawbacks such as high temperature, long reaction time, unsatisfactory yield and the use of toxic organic solvents and catalysts.



Scheme 1. One pot Three-component synthesis of spirooxindoles

Thus, we found that the development of some facile and green methods is urgency to construct such type of exceptionally bio-active heterocyclic compounds in aqueous media. Water is the attractive medium because of its low cost, safe and green nature. Additionally, it can also manipulate the reaction rate and selectivity due to its large dielectric constant, and extensive H-bonding nature.

Now a days, the governing approaches are the use of aqueous micellar medium to carry out a variety of multi-component reactions (MCRs). These methods have unique importance, since it addresses various work up difficulties that usually observed in simple aqueous medium.[xxxvi(a)] Micelles are active bunch of surfactant molecules possessing both hydrophobic and hydrophilic framework. They can collect the reactants within a small area, and stabilize intermediate and product.[xxxvi(b)] Hence, they provide numerous benefits such as increased solubility, regio- and stereo-selectivity, reaction rate, and high yield of the product.

Results and Discussion

Here, we proposed VB_1 catalyzed synthesis of spirooxindoles and its derivatives in aqueous micellar medium (**Scheme 1**). The present method is one-pot, multicomponent, green synthesis and to the best of our knowledge, this is the first synthesis of the given compound using VB1 in aqueous miceller medium.

Initially, we investigated optimization conditions with respect to both the catalyst and the solvent. For this purpose isatin (1), malanonitrile (2) and 5-amino-1,3-dimethyluracil (3) were chosen as model substrates for the synthesis of representative compound (4a) (Scheme 1). Firstly we performed the reaction without use of any surfactant and found that reaction does not proceeds and no product was obtained. Now to increase yield we have used cetyltrimethylammonium bromide (CTAB) as a surfactant, which participate in reaction significantly to encourage the reaction. As a trial, we performed the reaction with 8 mol% of CTAB in water but no significant change was observed. An encouraging change was noticed when the reaction was carried out with 10 mol% of CTAB in 50 mL water. This gave only 30% yield of the product (Table 1, entry 3). Surprisingly, the reaction afforded maximum 90% yield (Table 1, entry 4) when performed with 20 mol% of CTAB. No change in yield was noticed when concentration of CTAB was further increased (Table 1, entry 5,6). Besides CTAB, other surface active reagents, like sodium dodecylsulfate (SDS) and tetradecyltrimethylammonium bromide (TTAB) were also used to perform the reaction (Table 1, entries 7 and 8), but no satisfactory results were obtained as compared to CTAB.

Table 1: Effect of different surfactant on the yield of the reaction

Entry	Surfactant	Conc. (mol%)	Time (min)	Yield (%)
1	-	-	190	Traces
2	CTAB	8	190	Traces
3	CTAB	10	190	30
4	CTAB	20	40	90
5	CTAB	30	40	90
6	CTAB	40	40	90

7	SDS	20	30	30
8	TTAB	20	30	45

Lastly, to study the effect of solvents, we replaced water by other organic solvents but the results were not as good as in case of water (Table 2). It was also noticed that a higher reaction temperature (instead of room temperature) had no effect on the yield.

Table 2 Effect of different solvent on the yield of the reaction

Entry	Solvent	Time (min)	Yield (%)
1	Toluene	40	20
2	THF	30	70
3	CH_3CN	30	55
4	Hexane	30	30
5	1,4-Dioxane	30	50
6	Water	30	90

Once ideal conditions for conducting the reaction had been identified, the scope and limitations of the developed synthetic protocol was explored under the optimized reaction conditions with isatin having different substituents (Table 3). In all the cases the desired product was obtained in high yield and short reaction times (Table 3). It was observed that when an electron withdrawing group was present on the isatin, the reaction proceeded faster while the presence of an electron donating group slowed down the reaction (Table 3).

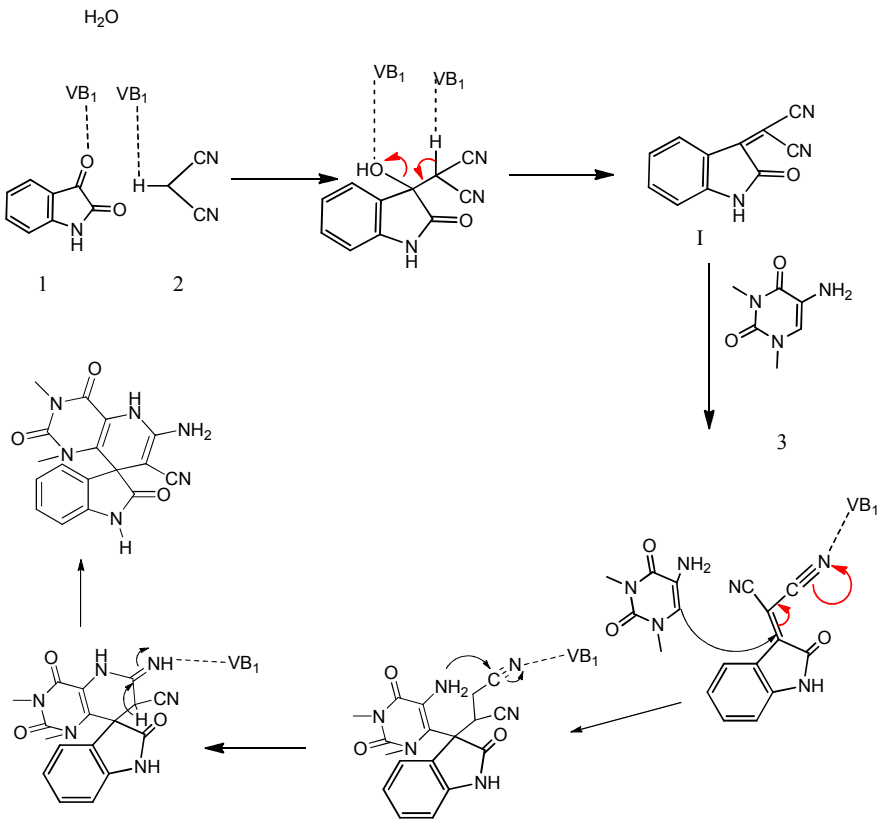
Table 3: Substrate scope[a]

Entry	R_1	R_2	Product	Time(h)	Yield(%)b
1	H	CN	4a	6	93
2	H	CO_2Et	4b	5	94
3	butyl	CN	4c	8	91
4	CH_3CHCO_2Et	CO_2Me	4d	6	93
5	allyl	CN	4e	6	95
6	H	CO_2Me	4f	6	93
7	allyl	CO_2Me	4g	8	90
8	allyl	CO_2Et	4h	8	93
9	CH_3CHCO_2Et	CN	4i	10	91
10	butyl	CO_2Me	4j	6	92
11	CH_3CHCO_2Et	CO_2Et	4k	8	95
12	butyl	CO_2Et	4l	8	94

a All reactions were carried out with **1** (1 mmol), **2** (1mmol), **3** (1mmol) in 5 mL of solvent under air.

b Isolated yields.

Formation of desired product seemed to be initiated by Knovenagel condensation of isatin and malononitrile to give intermediate **I** followed by Michael type addition between uracil **3** and **I** now the unstable intermediate **II** is formed which could not be isolated and undergoes simultaneous cyclization followed by air oxidation to finally give the desired product (Scheme 2).



Scheme 2. Plausible mechanism

Experimental Section

General procedure for the synthesis of spirooxindole derivatives (4a-4l)

In a 50 ml round bottom flask, a mixture of isatin derivative (1.0 mmol), activated methylene (1.0 mmol), 5-amino-1,3-dimethyluracil (1.0 mmol) and the VB_1 catalyst in water (50 mL) was taken for an appropriate period of time as indicated in Table 2. During the procedure, the reaction was monitored by TLC. Upon completion, the reaction mixture was diluted with hot ethanol (10 mL). The crude product was recrystallized from ethanol to afford the corresponding pure product.

Selected spectral data of some representative compounds

6′-Amino-1′,3′-dimethyl-2,2′,4′-trioxo-1′,3′,4′,5′-tetrahydro-2′*H*-spiro[indoline-3,8′-pyrido[3,2-*d*]pyrimidine]-7′-carbonitrile (4a): White solid; m.p. > 300 ^oC; ^1H NMR (300MHz, $CDCl_3$) δ:2.56 (s, 6H,), 6.71-7.56 (m, 7H), 8.56 (brs, 1H,); ^{13}C NMR(62.5 MHz, $CDCl_3$) δ: 27.19, 28.7, 53.9, 56.1, 101.1, 113.8, 116.2, 122.8, 122.8, 121.8, 128.8,131.0, 142.1, 148.0, 152.5, 154.5, 158.8; IR (KBr, Cm-^{1}): 3631, 3162, 3078, 2123, 1163, 1641, 1474, 682, 571; Anal. Calcd for $C_{17}H_{14}N_6O_3$: C, 58.28; H, 4.03; N,23.99; Found: C, 58.25; H, 4.07; N, 24.07.

Ethyl-6′-amino-1′,3′-dimethyl-2,2′,4′-trioxo-1′,3′,4′,5′-tetrahydro-2′*H*-spiro[indoline-3,8′-pyrido[3,2-*d*]pyrimidine]-7′-carboxylate (4b): White solid; m.p. > 300 ^oC; ^1H NMR (300MHz, $CDCl_3$) δ: 1.12 (t, J= 7.4 Hz), 2.63 (s, 6H), 4.10 (q, J= 5.1 Hz, 2H), 6.82-7.65 (m, 7H), 7.96 (brs, 1H,); ^{13}C NMR(62.5 MHz, $CDCl_3$)δ: 15.3,28.6, 31.7, 44.0, 47.4, 76.5, 104.8, 120.6, 125.0, 128.1, 133.0, 135.3, 145.0, 164.1, 166.5, 169.9,178.0, 178.9; IR (KBr, Cm-^{1}):3625, 3188, 3117, 1172, 1651, 1484, 682, 575; Anal. Calcd for$C_{19}H_{19}N_5O_5$: C, 57.43; H, 4.82; N, 17.62; Found: C, 57.51; H, 4.74; N, 17.67.

6′-Amino-1-butyl-1′,3′-dimethyl-2,2′,4′-trioxo-1′,3′,4′,5′-tetrahydro-2′*H*-spiro[indoline-3,8′-pyrido[3,2-*d*]pyrimidine]-7′-carbonitrile (4c): White solid; m.p. > 300 ^{o}C; ^{1}H NMR (300MHz, $CDCl_3$) δ: 1.23 (t, *J*= 2.1 Hz, 3H), 1.67-1.71 (m, 4H,), 2.82 (s, 6H), 4.17-4.25(m, 2H), 6.71-7.56 (m, 7H); ^{13}C NMR(62.5 MHz, $CDCl_3$) δ: 13.1,20.2, 29.1, 30.3, 30.4, 43.4, 54.1 55.7, 102.6, 115.7, 121.4, 122.6, 124.3, 127.0, 142.7, 143.6,152.9, 155.7, 161.4, 167.7; IR (KBr, Cm-^{1}): 3177, 3073, 2922, 2111, 1827,1652, 1454, 1161, 1122, 1011, 812, 681; Anal. Calcd for $C_{21}H_{22}N_6O_3$: C, 62.06; H, 5.46; N,20.68; Found: C, 61.92; H, 5.53; N, 20.74.

Methyl-6′-amino-1-(1-ethoxy-1-oxopropan-2-yl)-1′,3′-dimethyl-2,2′,4′-trioxo-1′,3′,4′,5′tetrahydro-2′*H*-spiro[indoline-3,8′-pyrido[3,2-*d*]pyrimidine]-7′-carboxylate (4d): White solid; m.p. > 300 ^{o}C; ^{1}H NMR (300MHz, $CDCl_3$) δ: 0.98 (t, *J*= 7.5 Hz), 1.40 (d, *J*= 7.6 Hz), 2.71 (s, 6H), 3.71 (s, 3H), 4.10 (q, *J*= 5.1 Hz, 1H), 4.55 (q, *J*= 7.7 Hz,2H), 6.87-7.63 (m, 7H); ^{13}C NMR(62.5 MHz, $CDCl_3$) δ: 14.1, 14.8, 29.4, 29.5, 41.1, 51.0, 61.2, 65.2, 81.6, 101.4, 117.4, 110.7, 122.6, 145.5, 148.4, 152.5, 157.0,163.5, 165.8, 167.8, 172.9, 174.1; IR (KBr, Cm-^{1}):3436, 3204, 2956, 1766, 1698, 1653, 1544,1497, 1428, 1251, 985, 764; Anal. Calcd for $C_{23}H_{25}N_5O_7$: C, 57.14; H, 5.21; N, 14.49; Found: C,57.27; H, 5.32; N, 14.56.

1-Allyl-6′-amino-1′,3′-dimethyl-2,2′,4′-trioxo-1′,3′,4′,5′-tetrahydro-2′*H*-spiro[indoline-3,8′-pyrido[3,2-*d*]pyrimidine]-7′-carbonitrile (4e): White solid; m.p. > 300 ^{o}C; ^{1}H NMR (300MHz, $CDCl_3$) δ: 2.84 (s, 6H), 4.20 (q, *J*=2, 4.5 Hz, 2H), 5.06 (dd, *J*= 1.6, 4.7 Hz, 1H), 5.57 (dd, *J*= 1.7, 10.2, 1H), 5.84-5.90 (m, 1H), 6.88-7.46 (m, 7H); ^{13}C NMR(62.5 MHz, $CDCl_3$) δ: 28.5, 29.0, 46.7, 51.2, 57.2, 102.4, 118.2, 121.7, 124.6,126.2, 131.0, 143.3, 152.5, 153.0, 162.8, 163.5, 165.8; IR (KBr, Cm-^{1}):3523, 3081, 3019, 2015,1694, 1621, 1473, 1162, 671, 564; Anal. Calcd for $C_{20}H_{18}N_6O_3$: C, 61.53; H,4.05; N, 21.53. Found: C, 61.61; H, 4.08; N, 21.60.

Methyl-6′-amino-1′,3′-dimethyl-2,2′,4-trioxo-1′,3′,4′,5′-tetrahydro-2′*H*-spiro[indoline-3,8′pyrido[3,2-*d*]pyrimidine]-7′-carboxylate (4f): White solid; m.p. > 300 ^{o}C; ^{1}H NMR (300MHz, $CDCl_3$) δ: 2.61 (s, 6H), 3.81 (s, 3H), 6.82-7.62 (m, 6H), 8.71 (brs, 2H); ^{13}C NMR(62.5 MHz, $CDCl_3$) δ: 27.8, 28.6, 42.2, 48.4, 51.4, 80.8, 100.9, 110.8, 117.4,122.6, 131.0, 131.3, 142.0, 154.5, 158.1, 161.5, 164.2, 168.7, 180.2; IR (KBr, Cm-^{1}): 3881, 3164,3073, 3062, 2905, 1863, 1686, 1667, 1471, 1157, 1138, 1016, 1022, 812, 679, 563; Anal. Calcd for $C_{18}H_{17}N_5O_5$: C, 56.39; H, 4.47; N, 18.27; Found: C, 56.46; H, 4.57; N, 18.33.

Conclusion

In summary, we have developed an efficient, multi-component, one pot synthesis of spirooxindoles and its derivatives in aqueous micellar medium by using Thiamine hydrochloride as a promoter. This methodology possess several advantages such as non-toxic and inexpensive catalysts, easy work-up procedure, use of green solvent, low temperature, aqueous micellar system and short reaction time. Therefore we concluded that this synthesis follows several view point of green chemistry.

Acknowledgements

Author Akhilesh Kumar is grateful to the CSIR for Fellowship.

.

References

i. X. Guo, W. Hu, *Acc. Chem. Res.* (2013), 46, 2427-2440

ii. Dandia, A.; Singh, R.; Khaturia, S.; Merienne, C.; Morgant, G.;Loupy, A. *Bioorg. Med. Chem.* (2006), 14, 2409–2417.

iii. (a) Khafagy, M. M.; El-Wahas, A. H. F. A.; Eid, F. A.; El-Agrody, A. M. Farmaco (2002), 57, 715–722; (b) Sebahar,P. R.;Williams, R. M. *J. Am. Chem. Soc.* (2000), 122, 5666–5667.

iv. (a) Ma, J.; Hecht, S. M. *Chem. Commun*. (2004), 1190–1191; (b) Edmondson, S.; Danishefsky, S. J.; Sepp-lorenzinol, L.; Rosen, N. *J. Am. Chem. Soc*. (1999), 121, 2147–2155.

v. Kang, T. H.; Matsumoto, K.; Murakami, Y.; Takayama, H.; Kitajima, M.; Aimi, N.; Watanabe, H. *Eur. J. Pharmacol.* (2002), 444, 39–45.

vi. (a) Williams, R. M.; Cox, R. J. Acc. Chem. Res. (2003), 36, 127–139; (b) Da Silva, J. F. M.; Garden, S. J.; Pinto, A. C. *J. Braz. Chem. So*c. (2001), 273–324.

vii. (a) Cui, C.-B.; Kakeya, H.; Osada, H. *Tetrahedron* (1996), 52, 12651–12666; (b) Cui, C.-B.; Kakeya, H.; Osada, H. J. Antibiot. (1996), 49, 832–833; (c) Leclercq, J.; De Pauw-Gillet, M.-C.; Bassleer, R.; Angenot, L. J. Ethnopharmacol. (1986), 15, 305–316.

viii. (a) Fischer, C.; Meyers, C.; Carreira, E. M. Helv. Chim. Acta (2000), 83, 1175–1181; (b) Alper, P. B.; Meyers, C.; Lerchner, A.; Siegel, D. R.; Carreira, E. M. *Angew.Chem.*, Int. Ed. (1999), 38, 3186–3189; (c) Redkin, R. Gr.; Shemchuk, L. A.; Chernykh, V. P.; Shishkinb, O. V.; Shishkina, S. V. Tetrahedron (2007), 63, 11444–11450; (d) Kumar, R. S.; Perumal, S. *Tetrahedron Lett*. (2007), 48, 7164–7168; (e) Sebahar, P. R.; Williams, R. M. *J. Am. Chem*. Soc. (2000), 122, 5666–5667; (f) Galliford, C. V.; Scheidt, K. A. Angew. Chem. (2007), 119, 8902–8912.

ix. (a) Hilton, S. T.; Ho, T. C. T.; Pljevaljcic, G.; Jones, K. *Org. Lett.* (2000), 2, 2639; (b) Kornet, M. J.; Thio, A. P. *J. Med. Chem*. (1976), 19, 892.

x. Chen, H.; Shi, D. *J. Comb. Chem*. (2010), 12, 571.

xi. M. Kidwai, A. Jahan, N.K. Mishra, Appl. Catal. A Gen. 425–426 (2012) 35–43.

xii. S.-L. Zhu, S.-J. Ji, Y. Zhang, *Tetrahedron* 63 (2007) 9365–9372.

xiii. G. Shanthi, G. Subbulakshmi, P.T. Perumal, *Tetrahedron* 63 (2007) 2057–2063.

xiv. S. Gao, C.H. Tsai, C. Tseng, C.-F. Yao, *Tetrahedron* 64 (2008) 9143–9149.

xv. M.M. Garima Kumari, *Eur. J. Med. Chem*. 46 (2011) 1181–1188.

xvi. M.M.-C. Lo, C.S. Newmann, S. Nagayams, E.O. Perlstein, S.L. Schreiber, *J. Am. Chem. Soc*. 127 (2005) 10130–10131.

xvii. V.V. Vintonyak, K. Warburg, H. Kruse, S. Grimme, K. Hübel, D. Rauh, H. Waldmann, Angew. Chem. *Int. Ed. Engl*. 49 (2010) 5902–5905.

xviii. B.K.S. Yeung, B. Zou,M. Rottmann, S.B. Lakshminarayana, S.H. Ang, S.Y. Leong, J. Tan, J. Wong, S. Keller-Maerki, C. Fischli, A. Goh, E.K. Schmitt, P. Krastel, E. Francotte, K. Kuhen, D. Plouffe, K. Henson, T. Wagner, E.A. Winzeler, F. Petersen, R. Brun, V. Dartois, T.T. Diagana, T.H. Keller, *J. Med. Chem*. 53 (2010) 5155–5164.

xix. A. Fensome, W.R. Adams, A.L. Adams, T.J. Berrodin, J. Cohen, C. Huselton, A. Illenberger, J.C. Kern, V.A. Hudak, M.A. Marella, E.G. Melenski, C.C. McComas, C.A. Mugford, O.D. Slayden, M. Yudt, Z. Zhang, P. Zhang, Y. Zhu, R.C. Winneker, J.E. Wrobel, *J. Med. Chem*. 51 (2008) 1861–1873.

xx. S. Yu, D. Qin, S. Shangary, J. Chen, G. Wang, K. Ding, D. McEachern, S. Qiu, Z. Nikolovska-Coleska, R. Miller, S. Kang, D. Yang, S. Wang, *J. Med. Chem*. 52 (2009) 7970–7973.

xxi. N. Azizi,S. Dezfooli, Mo. M.Hashemi, *Journal of Molecular Liquids* 194 (2014) 62–67.

xxii. (a) P. Khanna, S. S. Panda, L. Khanna, S. C. Jain, *Mini Rev*. *Org. Chem*. (2014), 11, 73-86; (b) J. Day, M. Uroos, R. A. Castledine, W. Lewis, B. McKeever-Abbas, J. Dowden, *Org*. *Biomol*. *Chem*., (2013), 11, 6502-6509; (c) T. Honda, *Pure Appl*. *Chem.* (2010), 82, 1773-1783; (d) C. V. Galliford, K. A. Scheidt, *Angew*. *Chem*. *Intl*. *Ed*. (2007), 46, 8748-8758.

xxiii. (a) D. B. Ramachary, C. Venkaiah, R. Madhavachary, *Organic Lett*., (2013), 15,

3042-3045 and references cited therein; (b) G. S. Singh, Z. Y. Desta, *Chem. Rev*. (2012), 112, 6104-6155.

xxiv. Song-Lei Zhu,a,b Shun-Jun Jia, and Yong Zhang Tetrahedron 63 (2007) 9365–9372

xxv. Gnanamani Shanthi, Ganesan Subbulakshmi and Paramasivan T. Perumal Tetrahedron 63 (2007) 2057–2063

xxvi. Li-Min Wang, Ning Jiao, Jun Qiu, Jian-Jun Yu, Jin-Qian Liu, Feng-Lou Guo, Ying Liu Tetrahedron 66 (2010) 339–343

xxvii. Shailesh P. Satasia, Piyush N. Kalaria, Jemin R. Avalani, Dipak K. Raval Tetrahedron 70 (2014) 5763e5767

xxviii. (a) A. Bazgir, G. Hosseini, R. Ghahremanzadeh, *ACS Comb. Sci*. (2013), 15, 530-534; (b) A. P. Antonchick, C. Gerding-Reimers, M. Catarinella, M. Schürmann, H. Preut, S. Ziegler, D. Rauh, H. Waldmann, *Nat Chem*. (2010), 2, 735-740.

xxix. N. R. Ball-Jones, J. J. Badillo, A. K. Franz, *Org. Biomol. Chem*. (2012), 10, 5165–5181.

xxx. (a)B.Yu,D-Q. Yu, H-M. Liu, *Eur. J. Med. Chem*. (2014), dx.doi.org/10.1016/j.ejmech.2014.06.056 and references cited therein; (b) A. Monteiro., L. M.Gonçalves, M. M. M. Santos, *Eur. J. Med. Chem*. 79, (2014), 266-272.

xxxi. Singh, S. B.; Tiwari, K.; Verma, P. K.; Srivastava, M.; Tiwari, K. P.; Singh, *J. Supramolecular Chem*, (2013), *25(5)*, 255.

xxxii. (a) Noonan, C.; Baragwanath, L.; Connon, S. J. *Tetrahedron Lett.,* (2008), *49*, 4003; (b) Dünkelmann, P.; Jung, D. K.; Nitsche, A.; Demir, A. S.; Siegert, P.; Lingen, B.; Baumann, M.; Pohl, M.; Müller, M. *J. Am. Chem. Soc.* (2002), *124*, 12084.

xxxiii. Orlandi, S.; Caporale, M.; Benaglia, M.; Annunziata, R. *Tetrahedron: Asymmetry*., (2003), *14*, 3827.

xxxiv. Sheldon, R. A. *Green Chem*. (2005), *7*, 267.

xxxv. Anastas, P.; Williamson, T.; *Green Chemistry*, Frontiers in Benign 33. Chemical Synthesis and Processes, University Press, London, (1998).

xxxvi. (a) Sobhani, S.; Parizi, Z. P.; *Tetrahedron*., (2011), *67*, 3540; (b) Ganguly, N.; Roy, S.; Mondal, P.; Saha, R. *Tetrahedron Lett.*, (2012), *53*, 7067.

Received on September1, 2017.