Iranian Journal of Organic Chemistry Vol. 6, No. 1 (2014) 1221-1226

One-pot three-component synthesis of α-amino phosphonates using 2,3-dibromosuccinic acid as catalyst under solvent-free conditions

Nourallah Hazeri * and Jasem Aboonajmi

Department of Chemistry, Faculty of Science, University of Sistan & Baluchestan, P. O. Box 98135-674 Zahedan, Iran.

Received: January 2014; Revised: January 2014; Accepted: January 2014

Abstract: For the first time, 2,3-dibromosuccinic acid was applied as catalyst for the one-pot, three-component synthesis of α-aminophosphonates from aldehydes, amines and trialkylphosphite under solvent-free condition at room temperature. This procedure has some advantages such as excellent yields, mild reaction conditions, short reaction time, lack of need for column chromatography, simple work-up, cheap and biodegradable catalyst.

Keywords: α-Aminophosphonate, Amines, Aldehydes, 2,3-Dibromosuccinic acid, Solvent-free.

Introduction

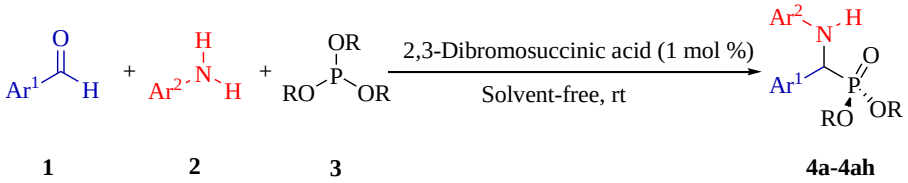
Due to the growing concern for the influence of organic solvents on the environment as well as on the human body, organic reactions without use of conventional organic solvents have attracted the attention of synthetic organic chemists [1]. Although a number of modern solvents such as fluorous media [2], $ScCO_2$ [3], ionic liquids [4], and water [5-6] have been extensively studied recently, not using a solvent at all is definitely the best option. Development of solvent-free organic reactions is thus gaining prominence [7-9].

The nitrogen atom is present in many natural products, biologically relevant molecules, pharmaceuticals, and dyes [10-12]. Among compounds containing nitrogen atom, α-aminophosphonates are important specially. α-Aminophosphonates as a kind of natural amino acid analogs occupy an important place, reveal diverse, interesting biological and biochemical properties [13-15]. Their potential as plant growth regulators [16], herbicidals [17], pharmacogenic agents [18], antibiotics [19], enzyme inhibitors [20], HIV protease [21], and antithrombotic agents [22] is well documented. As a result, various methodologies have been developed for the synthesis of α-amino phosphonates. Many of these methods are based on nucleophilic addition of phosphate to imines catalyzed by protic [23] Lewis acids like $BF_3.OEt_2$ [24], $SnCl_4$ [25], $ZnCl_2$ and $MgBr_2$ [26], or by base [27]. However, these reactions can not proceed in one-pot procedure from reaction between an aldehyde, an amine and a phosphite, because the amines and water that exist during imine formation can decompose or deactivate the Lewis acids [28]. This drawback has been overcome by some recent methods using metaltriflates [$M(OTf)_n$, M = Li, Mg, Al, Cu, Ce] [29], NaH_2PO_4 [30], $TaCl_5$-SiO_2 [31], $InCl_3$ [32], $ZrOCl_2 \cdot 8H_2O$ [33-34], $H_3PW_{12}O_{40}$ [35], SmI_2 [36], oxalic acid [37], CSA [38], $Mg(ClO_4)_2$ [39], CAN [40], Boric acid [41], $CoCl_2.6H_2O$ [42], $PhNMe_3Cl$ [43], Yttria-zirconia [44], TiO_2 [45], $SbCl_3/Al_2O_3$ [46], Amberlite-IR 120 [47], Amberlyst-15 [48], $In(OTf)_3$ [49], microwave assisted [50], and CF_3CO_2H [51]. However, most of these methods have drawbacks, such as toxic catalysts, environmental pollution caused by using an organic solvent, expensive catalyst, difficulty of preparation, unavailable reagents, prolonged reaction times, unsatisfactory yields, and harsh reaction conditions. Therefore, it is necessary to further develop an efficient one-pot multi-component synthesis of α-amino phosphonates which is devoid of these problems.

*Corresponding author. Tel: (+98) 541 2416586, Fax: (+98) 541 2416586, E-mail: nhazeri@chem.usb.ac.ir

It is well known that homogeneous catalysts have gained increasing attraction in recent years due to their operational simplicity, low cost, ease of preparation and handling, stability, and economic advantages. One of these homogeneous catalysts is 2,3-dibromosuccinic acid.

As part of our continuing interest in developing methods for the synthesis of α-aminophosphonates [52-60], herein, we report a green, simple and efficient protocol for the synthesis of α-aminophosphonates through one-pot three-component reactions of aldehydes, amines, and trialkylphosphite using catalytic amounts of 2,3-dibromosuccinic acid (1 mol%) under solvent-free conditions at room temperature (Scheme **1**).



1 **2** **3** **4a-4ah**

Scheme 1: Synthesis of α-aminophosphonates **4a-4ah.**

Results and discussion

First, in order to optimize the reaction conditions, the reaction of 4-chlorobenzaldehyde (1 mmol), aniline (1 mmol), and trimethylphosphite (1 mmol) was carried out using different quantities of 2,3-dibromosuccinic acid under different conditions at room temperature. As can be seen in (Table **1**, entry 6), the best result in the presence of 2,3-dibromosuccinic acid (0.0027 g, 1 mol %) of the catalyst under solvent-free conditions. Poor yield (52%) was obtained when the reaction was carried out in the absence of 2,3-dibromosuccinic acid at room temperature under solvent-free conditions for 24 h (Table **1**, entry 7). Structurally diverse aldehydes, amines and phosphites were used in optimized conditions to afford the corresponding α-aminophosphonates in high to excellent yields.

Table 1: Optimization of the reaction conditions for the synthesis of α-aminophosphonates 4 [a].

Entry	Catalyst (mol%)	Time (min)	Isolated Yield (%)
1	20	1	94
2	15	1	95
3	10	1	97
4	5	1	97
5	2	1	97
6	1	1	97
7	No	24 h	52

[a] Reaction conditions: 4-chlorobenzaldehyde, aniline, and trimethylphosphite under solvent-free conditions at room temperature.

Thus, several reactions of different aldehydes, amines, and trialkylphosphite were examined in the presence of 2,3-dibromosuccinic acid as a catalyst under solvent-free conditions at room temperature (Table **2**). In all cases, the one-pot, three-component reaction proceeded smoothly to afford the corresponding α-aminophosphonates in good to excellent yields. As shown in Table **2**, the reaction of anilines with a variety of aromatic aldehydes containing electron-deficient and / or electron-releasing groups and trimethyl / triethylphosphite proceeded to afford α-aminophosphonates in shorter reaction times and in good to excellent yields. On the basis of experimental results, the rates of all reactions in the presence of triethylphosphite were reduced in comparison with trimethylphosphite under constant conditions.

We have also prepared one new analogs of these compounds in excellent yields (Table **2**, entry 34). These new compounds were characterized by elemental analyses, IR, ^{1}H, ^{13}C, ^{31}P NMR, and mass spectroscopies.

A plausible mechanism is shown in scheme **2**. It is believed to involve the formation of activated imine **A** by the addition of aldehyde and amine. Then phosphite is added to the C=N bond of imine **A** to give phosphonium intermediate **B**. This phosphonium intermediate undergoes reaction with water to give the α-aminophosphonates **4** and ethanol [38, 41].

To show the capability of the present work in comparison with reported conditions in the literature, we compared the results of 2,3-dibromosuccinic acid with the other catalysts for the synthesis of compounds **4c**. As shown in (Table **3**), 2,3-dibromosuccinic can act as effective catalyst with respect to reaction times and yields of products.

Conclusion

In summary, we have developed a simple and efficient method for the one-pot, three-component

synthesis of α-aminophosphonates in the presence of catalytic amount of 2,3-dibromosuccinic acid (1 mol%) under solvent-free conditions. The advantages of this protocol are excellent yields, short reaction time, mild reaction conditions, higher availability, low costs, more environmentally friendly, lack of need for column chromatography and simple work-up procedure.

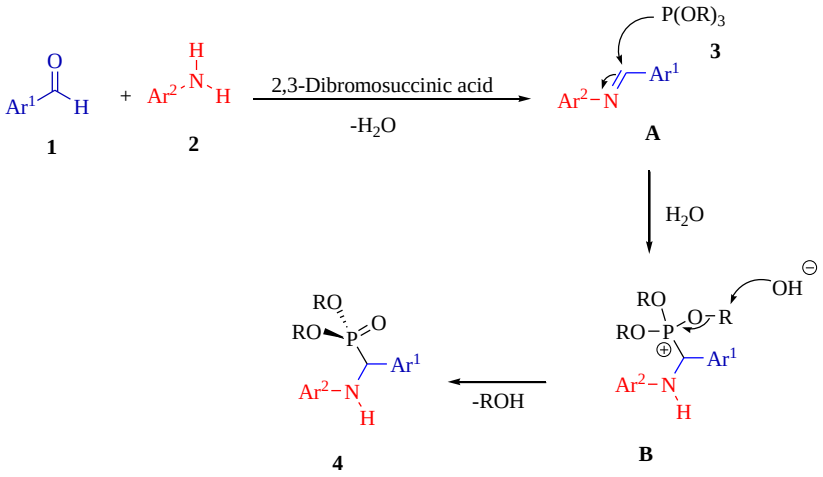
Table 2: Preparation of α-aminophosphonates 4a-4ah.

Entry	Ar^1	Ar^2	R	Product	Time (min)	Yiled[a](%)	M.p. / °c	Ref.[b]
1	Ph	Ph	Me	4a	5	90	91-93	39
2	Ph	Ph	Et	4b	18	88	87-88	45
3	4-Cl-C_6H_4	Ph	Me	4c	1	97	137-140	37
4	4-Cl-C_6H_4	Ph	Et	4d	6	95	58-59	45
5	4-OMe-C_6H_4	Ph	Me	4e	1	97	122	41
6	4-OMe-C_6H_4	Ph	Et	4f	17	97	108	46
7	2,4-di-OMe-C_6H_3	4-OMe-C_6H_4	Me	4g	5	91	131-133	54
8	4-NO_2-C_6H_4	Ph	Me	4h	7	93	124-125	43
9	4-NO_2-C_6H_4	Ph	Et	4i	14	90	126-127	47
10	2,4-di-Cl-C_6H_3	Ph	Me	4j	3	85	109-111	59
11	2,4-di-OMe-C_6H_3	Ph	Me	4k	1	95	146-148	57
12	2,4-di-OMe-C_6H_3	Ph	Et	4l	15	84	98-99	59
13	2-Cl-C_6H_4	Ph	Me	4m	1	95	132-134	37
14	2-Cl-C_6H_4	Ph	Et	4n	8	94	88-89	45
15	2,5-di-OMe-C_6H_3	Ph	Me	4o	1	95	121-122	58
16	4-Me-C_6H_4	Ph	Me	4p	1	98	113-115	41
17	4-Me-C_6H_4	Ph	Et	4q	10	92	63-65	59
18	3-NO_2-C_6H_4	3-NO_2-C_6H_4	Et	4r	30	86	158-159	49
19	Ph	4-Cl-C_6H_4	Me	4s	3	93	88-89	50
20	4-NO_2-C_6H_4	4-OMe-C_6H_4	Me	4t	15	90	117-119	50
21	4-OMe-C_6H_4	4-OMe-C_6H_4	Me	4u	8	85	184-185	51
22	4-F-C_6H_4	Ph	Et	4v	22	93	79-80	47
23	2,5-di-OMe-C_6H_3	4-Cl-C_6H_4	Me	4w	1	90	111-113	54
24	2-Me-C_6H_4	Ph	Me	4x	1	94	132-134	57
25	3-Cl-C_6H_4	Ph	Me	4ay	2	95	98-100	48
26	4-OH-3-OMe-C_6H_3	Ph	Me	4z	33	83	110-112	56
27	4-OH-3-OMe-C_6H_3	4-Me-C_6H_4	Me	4aa	40	81	104-107	56
28	2,4-di-OMe-C_6H_3	2-CN-C_6H_4	Me	4ab	38	75	88-90	56
29	3-NO_2-C_6H_4	Ph	Et	4ac	10	98	95-97	47
30	4-OMe-C_6H_4	3-NO_2-C_6H_4	Et	4ad	26	86	152-153	49
31	4-OMe-C_6H_4	4-F-C_6H_4	Et	4ae	20	94	52-53	45
32	2,6-di-Cl-C_6H_3	4-Br-C_6H_4	Me	4af	2	90	94-96	60
33	2,3-di-OMe-C_6H_3	4-Br-C_6H_4	Me	4ag	1	97	135-136	60
34	4-F-C_6H_4	4-Cl-C_6H_4	Me	4ah	30	90	102-103	*C*

[a] Yields refer to the pure isolated products. [b] All known products have been reported previously in the literature and were characterized by comparison of IR and NMR spectra with authentic samples. [c] The new compound synthesized in this work.

Table 3: Comparison of 2,3-dibromosuccinic acid with previously reported catalyst for the synthesis of α-aminophosphonate 4c.

Entry	Catalyst	Conditions	Time	Yield (%)	Ref.
1	Boric acid	Solvent-free/ rt	15 min	96	41
2	$CoCl_2.6H_2O$	Solvent-free/ rt	10 min	95	42
3	Oxalic acid	Solvent-free/ 50 °C	2h	91	37
4	$Al(H_2PO_4)_3$	Solvent-free/ 100 °C	12 min	95	58
5	PPA-SiO_2	Solvent-free/ 80 °C	20 min	95	57
6	$H_3PW_{12}O_{40}$	CH_2Cl_2/ rt	<15 min	92	35
7	$PhNMe_3Cl$	CH_2Cl_2/ 40 °C	3 h	74	43
8	2,3-Dibromosuccinic acid	Solvent-free/ rt	1 min	97	This work



Scheme 2: Plausible mechanism for the synthesis of α-aminophosphonates 4a-4ah.

Experimental

Apparatus and analysis:

Melting points and IR spectra were measured on an Electrothermal 9100 apparatus and a JASCO FT/ IR-460 plus spectrometer, respectively. The ^1H, ^{13}C, and ^{31}P NMR spectra were obtained on Bruker DRX-400 Avance instruments with $CDCl_3$ and Acetone-d_6 as a solvent. Elemental analyses were performed using a Heraeus CHN-O-Rapid analyzer. Mass spectra were recorded on an Agilent Technology (HP) spectrometer operating at an ionization potential of 70 eV. All reagents and solvents obtained from Fluka and Merck were used without further purification.

General Procedure for the Synthesis of α-Aminophosphonates (4a-4ah):

The mixture of aldehyde (1 mmol), amine (1 mmol), and 2,3-dibromosuccinic acid (1 mol%) were stirred for a few minutes. Then trimethyl / triethylphosphite (1 mmol) was added, and the reaction mixture was stirred at room temperature for the appropriate time as indicated in Table **2**. The progress of reactions was monitored by TLC (ethyl acetate/*n*-hexane, 1/4). After completion of the reaction, the reaction mixture was washed with water (3 × 10 mL). The catalyst is soluble in water and was removed from the reaction mixture. The crude product was washed with the mixture of *n*-hexane/Et_2O (5/2) to give pure products.

Spectral data for the synthesized compounds (4a, 4c, 4aa and 4ah):

Compound **4a**: white solid, mp. 91-93 °C; FT-IR (KBr) υ: 3294 (NH); 1236 (P═O); ^1H NMR (400 MHz, $CDCl_3$): δ_H 3.51 (3H, d, $^3J_{PH}$= 10.4 Hz, P-OCH_3), 3.80 (3H, d, $^3J_{PH}$= 10.4 Hz, P-OCH_3), 4.83 (1H, br, NH), 4.84 (1H, d, $^2J_{PH}$= 24.8 Hz, CHP), 6.64 (2H, d, *J* = 7.6 Hz, ArH), 6.74 (1H, t, *J* = 7.4 Hz, ArH), 7.14 (2H, t, *J* = 8.0 Hz, ArH), 7.31 (1H, t, *J* = 7.8 Hz, ArH), 7.38 (2H, t, *J* = 7.6 Hz, ArH), 7.52 (2H, d, *J* = 8.0 Hz, ArH).

Compound **4c**: white solid, mp. 137-140 °C; FT-IR (KBr) υ: 3310 (NH); 1232 (P═O); ^1H NMR (400 MHz,

Acetone-d_6): δ: 3.57 (3H, d, $^3J_{PH}$= 10.8 Hz, P-OCH_3), 3.76 (3H, d, $^3J_{PH}$= 10.4 Hz, P-OCH_3), 5.10 (1H, d, $^2J_{PH}$= 25.2 Hz, CHP), 5.76 (1H, br, NH), 6.63 (1H, t, *J* = 7.2 Hz, ArH), 6.81 (2H, d, *J* = 8.0 Hz, ArH), 7.08 (2H, t, *J* = 7.8 Hz, ArH), 7.39 (2H, d, *J* = 8.0 Hz, ArH), 7.62 (2H, d, *J* = 8.4 Hz, ArH).

Compound **4aa**: white solid, mp. 104-107 °C; FT-IR (KBr) υ: 3365 (NH), 3260 (br, OH), 1265 (P=O); ^{1}HNMR ($CDCl_3$, 400 MHz) δ: 2.22 (s, 3H, ArMe), 3.53, 3.79 (2d, 6H, J_{HP} = 10.4 Hz, $P(OMe)_2$), 3.88 (s, 3H, OMe), 4.71 (d, 1H, J_{HP} = 22.4 Hz, P-C-H), 4.50, 5.75 (2br, 2H, NH, OH), 6.55 (d, 2H, J_{HH} = 8.0, HAr), 6.90 (d, 1H, J_{HH} = 8.0 Hz, HAr), 6.95 (d, 2H, J_{HH} = 8.0 Hz, HAr), 6.96 (s, 1H, HAr), 7.02 (s, 1H, H_{Ar}).

Compound **4ah**: white solid, mp. 102-103 °C; FT-IR (KBr) υ: 3301 (NH); 1234 (P═O); ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 3.54, 3.87 (2d, 6H, J_{HP}=10.4 Hz, $P(OMe)_2$), 4.64 (br, H, NH), 5.18 (d, 1H, J_{HP}=24.8 Hz, P-C-H), 6.57 (d, 2H, J_{HH}=8.0, H_{Ar}), 7.08-7.32 (m, 5H, H_{Ar}), 7.52 (t, 1H, J_{HH}=8.0 Hz, H_{Ar}); ^{13}C NMR ($CDCl_3$, 100MHz) δ: 47.8 (d, J_{CP}=156.0 Hz, P-CH), 53.9, 54.0 (2d, J_{CP}=7.0 Hz, $2P(OMe)_2$), 114.8 (s, C_{Ar}), 115.4 (dd, J_{CF}=20.0 Hz, C_{Ar}), 122.8 (d, J_{CF}=13.0 Hz, C_{Ar}), 129.1 (s, C_{Ar}), 129.9 (d, J_{CP}=8.0 Hz, C_{Ar}), 140.3 (d, J_{CP}=15.0 Hz, C_{Ar}), 160.6 (d, J_{CF}=244.0 Hz,C_{Ar}); ^{31}P NMR ($CDCl_3$, 162 MHz) δ: 24.08; MS (EI, 70 eV) *m/z* (%): 345 (M^++2, 7), 343 (M^+, 20), 234 (100), 110 (6); Anal. calcd for $C_{15}H_{16}ClFNO_3P$: C, 52.42; H, 4.69; N, 4.08; found C, 52.57; H, 4.86; N, 4.16.

Acknowledgments

We gratefully acknowledge financial support from the Research Council of University of Sistan and Baluchestan.

References

[1] Knochel, P.; Houk, K. N.; Kessler, H. Ed. Modern Solvents In Organic Synthesis, Topics In Current Chemistry, Springer, Berlin, **1999**, 206.
[2] Curran, D. P. *Pure. Appl. Chem*. **2000**, *72*, 1649-1653.
[3] Leitner, W. *Top. Curr. Chem.* **1999**, *206*, 107-132.
[4] Welton, T. *Chem. Rev.* **1999**, *99*, 2071-2084.
[5] Li, C. J.; Chan, T. H. Organic Reactions in Aqueous Media: John Wiley, New York, **1997**.
[6] Grieco, Pa. Ed. Organic Reactions in Water: Blackie Academic and Professional, London, **1998**.
[7] Toda, F. *Acc. Chem. Res.* **1995**, *28*, 480-486.
[8] Metzger, J. O. *Angew. Chem. Int. Ed.* **1998**, *37*, 2975-2978.
[9] Tanaka, K.; Toda, F. *Chem. Rev*. **2000,** *100*, 1025-1074.
[10] Thomas, G. Medicinal Chemistry; Wiley: New York, **2000**.
[11] Pozharskii, A. F.; Soldatenkov, A. T.; Katritzky, A. R. Heterocycles in Life and Society; Wiley: New York, **1997**.
[12] Horton, D. A.; Bourne, G. T.; Smythe, M. L. *Chem. Rev*. **2003**, *103*, 893-930.
[13] Redmore, D. Topics in Phosphorous Chemistry. Griffith E J, Grayson M. (Eds.), Wiley: New York, **1976**.
[14] Savignac, P.; Iorga, B. Modern Phosphonate Chemistry. CRC Press: Boca Raton, FL, **2003**.
[15] Zefirov, N. S.; Matveeva, E. D. *Arkivoc*. **2008**, *2008*, 1-17.
[16] Emsley, J.; Hall, D. Chemistry of Phosphorous. Harper and Row: London, **1976**, 494.
[17] Hassal, C. H.; Hahn, E. F. Antibiotics, Springer: Berlin, **1983**, *VI*, 1-11.
[18] Baylis, E. K.; Campbell, C. D.; Dingwall, J. G. 1- *J. Chem. Soc. Perkin. Trans 1*, **1984**, 2845-2853.
[19] Atherton, F. R.; Hassal, C. H.; Lambert, R. W. *J. Med. Chem.* **1986**, *29*, 29-40.
[20] Allen, M. C.; Fuhrer, W.; Tuch, B.; wade, R.; Wood, J. M. *J. Med. Chem.* **1989**, *32*, 1652-1661.
[21] Stowasser, B.; Budt, K. H.; Jian, Q. L.; Peyman, A.; Ruppert, D. *Tetrahedron Lett*. **1992**, *33*, 6625-6628.
[22] Meyer, J. H.; Barlett, P. A. *J. A. Chem. Soc.* **1998**, *120*, 4600-4609.
[23] Petrov, K. A.; Chauzov, V. A.; Erkhian, T. S. *Usp. Khim*. **1974**, *3*, 2045 [*Chem Abstr*, 1975, 82: 449].
[24] Ha, H. J.; Nam, G. S. *Synth. Commun.* **1992**, *22*, 1143-1148.
[25] Laschat, S.; Kunz, H. *Synthesis* **1992**, 90-94.
[26] Zon, J. *Pol. J. Chem*. **1981**, *55*, 643-646.
[27] Pudovik, A. N. *Dokl. Akod. Nauk. SSSR.* **1952**, *83*, 865 [*Chem Abstr*, 1953, 47: 4300].
[28] Yokomatsu, T.; Yoshida, Y.; Shibuya, S. *J. Org. Chem*. **1994**, *59*, 7930-7933.
[29] Firouzabadi, H.; Iranpoor, N.; Sobhani, S. *Synthesis* **2004**, 2692-2696.
[30] Karimi-Jaberi, Z.; Amiri, M.; Sadeghi, N. *Synth. Commun.* **2010**, *40*, 2948-2953.
[31] Chandrasekhar, S.; Prakash, S. J.; Jagadeshwar, V.; Narsihmulu, C. *Tetrahedron Lett.* **2001**, *42*, 5561-5563.
[32] Ranu, B. C.; Hajra, A.; Jana, U. *Org. Lett.* 1999, *1*, 1141-1143.
[33] Bhagat, S.; Chakraborti, A. K. *J. Org. Chem.* **2008**, *73*, 6029-6032.
[34] Bhanushali, M. J.; Nandurkar, N. S.; Jagtap, S. R.; Bhanage, B. M. *Synth. Commun*. **2009**, *39*, 845-859.
[35] Heydari, A.; Hamidi, H.; Pouayoubi, M. *Catal. Comuun.* **2007**, *8*, 1224-1226.
[36] Xu, F.; Luo, Y. Q.; Deng, M. Y.; Shen, Q. One-Pot *Eur. J. Org. Chem.* **2003**, *2003*, 4728-4730.
[37] Vahdat, S. M.; Baharfar, R.; Tajbakhsh, M.; Heydari, A.; Baghbanian, S. M.; Khaksar, S. *Tetrahedron Lett.* **2008**, *49*, 6501-6504.
[38] Shinde, P. V.; Kategaonkar, A. H.; Shingate, B. B.; Shingare, M. S. *Tetrahedron Lett.* **2011**, *52*, 2889-2892.

[39] Bhagat, S.; Chakraborti, A. K. *J. Org. Chem.* **2007**, *72*, 1263-1270.
[40] Kasthuraiah, M.; Kumar, K. A.; Reddy, C. S.; Reddy, C. D. *Heteroat. Chem.* **2007**, *18*, 2-8.
[41] Karimi-Jaberi, Z.; Amiri, M. *Heteroatom Chem.* **2010**, *21*, 96-98.
[42] Karimi-Jaberi, z.; Zare, H.; Amiri, M.; Sadeghi, N. *Chin. Chem. Lett.* **2011**, *22*, 559-562.
[43] Heydari, A.; Arefi, A. *Catal. Commun.* **2007**, *8*, 1023-1026.
[44] Ramalingam, S.; Kumar, P. *Catal. Lett.* **2008**, *125*, 315-319.
[45] Sarvari, M. H.; *Tetrahedron* **2008**, *64*, 5459-5466.
[46] Ambica, K. S.; Taneja, S. C.; Hundal, M. S. Kapoor, K. K. *Tetrahedron Lett.* **2008**, *49*, 2208-2212.
[47] Bhattacharya, A. K.; Rana, K. C. *Tetrahedron Lett.* **2008**, *49*, 2598-2601.
[48] Tajbakhsh, M.; Heydari, A.; Alinezhad, H.; Ghanei, M.; Khaksar, S. *Synthesis* **2008**, 352-354.
[49] Ghosh, R.; Maiti, S.; Chakraborty, A.; Maiti, D. A. *J. Mol. Catal. A: Chem.* **2004**, *210*, 53-57.
[50] Mu, X. –J.; Lei, M. –Y.; Zou, J. –P.; Zhang, W. *Tetrahedron Lett.* **2006**, *47*, 1125-1127.
[51] Akiyama, T.; Sanada, M.; Fuchibe, K. *Synlett* **2003**, 1463-1464.
[52] Rostamizadeh, M.; Maghsoodlou, M. T.; Hazeri, N.; Habibi-Khorassani, S. M.; Leishams, L. *Phosphorus Sulfur Silicon Relat. Elem.* **2011**, *186*, 334-337.
[53] Maghsoodlou, M. T.; Habibi-Khorassani, S. M.; Heydari, R.; Hazeri, N.; Sajadikhah, S. S.; Rostamizadeh, M. *Arab. J. Chem.* **2011**, *4*, 481-485.
[54] Rostamizadeh, M.; Maghsoodlou, M. T.; Hazeri, N.; Khorassani, S. M. H.; Sajadikhah, S. S.; Maleki, N.; Shahkarami, Z. *Lett. Org. Chem.* **2010**, *7*, 542-544.
[55] Lashkari, M.; Hazeri, N.; Maghsoodlou, M. T.; Khorassani, S. M. H.; AkbarzadehTorbati, N.; Hosseinian, Asghar.; García-Granda, S.; Torre-Fernández, L. *Heteroatom. Chem*. **2013**, *24*, 58-65.
[56] Hazeri, N.; Maghsoodlou, M. T.; Khorassani, S. M. H.; Aboonajmi, J.; Lashkari, M.; Sajadikhah, S. S. *Res. Chem. Intermed*. DOI 10.1007/s11164-013-1081-8.
[57] Maghsoodlou, M. T.; Habibi-Khorasani, S. M.; Heydari, R.; Hazeri, N.; Sajadikhah, S. S.; Rostamizadeh, M.; Keishams, L. *Turk. J. Chem.* **2010**, *34*, 565-570.
[58] Maghsoodlou, M. T.; Habibi-Khorassani, S. M.; Heydari, R.; Hazeri, N.; Sajadikhah, S. S.; Rostamizadeh, M. *Chin. J. Chem.* **2010**, *28*, 285-288.
[59] Maghsoodlou, M. T.; Habibi-Khorassani, S. M.; Hazeri, N.; Rostamizadeh, M.; Sajadikhah, S. S.; Shahkarami, Z.; Maleki, N. *Heteroatom Chem.* **2009**, *20*,316-318.
[60] Maghsoodlou, M. T.; Heydari, R.; Habibi-Khorassani, S. M.; Hazeri, N.; Sajadikhah, S. S.; Rostamizadeh, M.; Lashkari, M. *Synth. Commun*. **2012**, *42*, 136-143.