Note

PEG-N_2O_4 System as an Efficient Reagent both for the Rapid Oxidation of Urazoles and 1,4-Dihydropyridines under Nonaqueous Conditions

Mohammad Ali Zolfigol,[a,*] Ezat Ghaemi,[a] Elaheh Madrakian[a] and Khodabakhsh Niknam[b]
[a]*Faculty of Chemistry, Bu-Ali Sina University, Hamedan, 6517838683, Iran*
[b]*Chemistry Department, Faculty of Sciences, Persian Gulf University, Bushehr 75169, Iran*

N_2O_4 was easily impregnated on polyethyleneglycol to give a stable reagent. Polyethyleneglycol-N_2O_4 (**PEG-N_2O_4**) system was used as an effective oxidizing agent for the oxidation of urazoles and bis-urazoles to their corresponding triazolinediones and also for the aromatization of 1,4-dihydropyridines into the corresponding pyridine derivatives under mild conditions at room temperature with good to excellent yields.

Keywords: Dinitrogen tetroxide; Polyethyleneglycol; Oxidation; Urazoles; Bis-urazoles; 1,4-Dihydropyridines.

INTRODUCTION

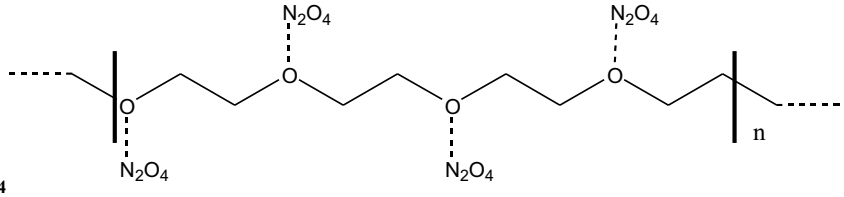
Polymer-supported reagents and catalysts have been widely applied in organic transformations. Immobilization of reactive species on a polymer-support could provide many important advantages over analogous homogeneous systems; for example, separation of the support from the reaction mixture can be achieved by simple filtration aiding isolation and purification procedures. Also, excess of polymeric reagent can be readily employed without incurring an increase in work-up. Transition metal complexes and optically active catalysts might be efficiently retained for re-use, and noxious or toxic species might be encapsulated when bound to a macromolecule, with obvious advantages in environmental terms. Also these reagents have many other advantages such as simple experimental procedures, stability, easy handling and minimal chemical wastes compared to their traditional homogeneous reagents.[1-3]

Dinitrogen tetroxide as an important industrial chemical is commercially supplied at low price in a cylinder, and can be used directly or in the form of liquid (b.p. 21 ºC) collected by transfer distillation into an ice-cooled vessel. Apart from difficulties in handling the poisonous and corrosive dinitrogen tetroxide, the biggest disadvantage of utilizing gaseous N_2O_4 in organic reactions is its high reactivity which usually causes undesired side reactions. In order to avoid these problems the reactions are usually performed at low temperature and careful control of reaction conditions is needed.[4] In recent years some reports were published on the use of N_2O_4 complexes of organic and inorganic compounds such as 18-crown-6 ether/N_2O_4,[5] polyvinylpyrolidone/N_2O_4,[6] $M(NO_3)_x.yN_2O_4$,[7] activated charcoal/N_2O_4,[8] N_2O_4/SiO_2,[9] silica acetate-N_2O_4,[10] calix[4]-arene/N_2O_4,[11] DMF-NO_2,[12] and (tributyl phosphate-NO_2, polyethylene glycol-NO_2, dioxane-NO_2) [13] as useful reagents that solve many difficulties in handling and increase selectivity of organic reactions. In continuation of our investigation on the preparation of N_2O_4 complexes, we now report on the application of N_2O_4 impregnated polyethyleneglycol as a cheap reagent made from available sources. Polyethyleneglycols (**PEGs**) are important components of crown ethers, cryptands, and other ion receptors[14] and their capability of binding with different ions have been widely investigated.[15] This reagent polyethyleneglycol-N_2O_4 (**PEG-N_2O_4**) was easily prepared by bubbling N_2O_4 gas through a solution of polyethylene glycol in cold CH_2Cl_2 (Scheme I).

Herein, we wish to report the use of polyethyleneglycol-N_2O_4 complex as an efficient oxidizing agent both for the oxidation of urazoles and bis-urazoles to their corresponding triazolinediones and aromatization of 1,4-dihy-

* Corresponding author. Fax: +98 811 8257407; E-mail: zolfi@basu.ac.ir and mzolfigol@yahoo.com (Mohammad Ali Zolfigol); E-mail: niknam@pgu.ac.ir and khniknam@gmail.com (Khodabakhsh Niknam)

Scheme I



PEG-N_2O_4

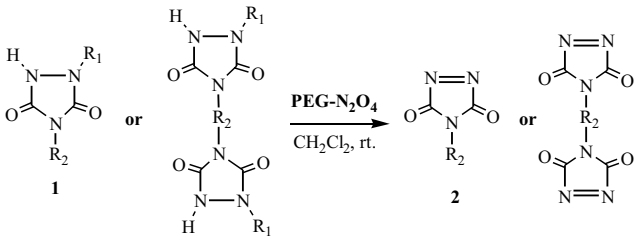
dropyridines into corresponding pyridine derivatives in nonaqueous conditions.

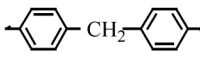
RESULTS AND DISCUSSION

Oxidation of Urazoles

4-Substituted-1,2,4-triazole-3,5-diones (**TAD**s) have been used both as substrates and reagents in various organic reactions. For example, they have been used in Diels-Alder, ene or [2+2] cycloadditions, dehydrogenation reactions, electrophilic aromatic substitution, condensation of dicarbonyl compounds, and oxidation of alcohols to aldehydes and ketones.[16] Very recently, aromatization of 1,4-dihydropyridines and pyrazolines as well as oxidation of thiols with **TAD**s have been reported.[17] The unusual reactivity of **TAD**s (**2**, **4**) makes them interesting and also hard to prepare and purify.[18] It is interesting to note that 4-phenyl-1,2,4-triazoline-3,5-dione (**2f**) is an extremely reactive dienophile and enophile which is at least 1000 times more reactive than tetracyanoethylene in the Diels-Alder reaction with 2-chlorobutadiene and 2000 times more reactive than maleic anhydride.[16] All known methods of synthesis of these compounds (1,2,4-triazolidine-3,5-diones) require oxidation of the corresponding urazoles (**1, 3**). Although a variety of reagents are capable of efficient oxidations of urazoles (**1, 3**) to **TAD**s, this transformation is not easy because these compounds are very sensitive to the oxidizing agents and reaction conditions. In addition, most of the reported reagents produce by-products which either destroy or are difficult to remove from the sensitive triazolinediones. Another major drawback of the older procedures is their use of reagents which are either highly toxic or impart serious disposal problems (or both).[19-23] Recently, we among many others, have demonstrated that application of heterogeneous systems, for the above reported oxidations, has many advantages over their liquid phase counterparts such as simple experimental procedures, mild reaction conditions and minimization of chemical wastes.[5b,24] Herein, we wish to report a simple, cheap and convenient method for the effective oxidation of urazoles (**1**) and bis-urazoles (**3**) to their corresponding triazolinediones (**2**, **4**) by using **PEG-N_2O_4** as an oxidizing agent (Scheme II).

Scheme II



	R_1	R_2
1a	H	Me
1b	H	Et
1c	Na	n-Pr
1d	H	n-Bu
1e	H	Cyclohexyl
1f	H	Ph
1g	H	4-Cl-Ph
1h	H	3,4-Cl_2-Ph
1i	H	4-NO_2-Ph
1j	H	4-OMe-Ph
1k	H	4-*t*-Bu-Ph
1l	H	4-Naphtyl
3a	H	

A good range of urazoles (**1**) and bis-urazoles (**3**) were subjected to the oxidation reaction in the presence of the oxidizing agents **PEG-N_2O_4** in dichloromethane. All oxidation reactions were performed under mild and completely heterogeneous conditions, at room temperature with good to excellent yields (Table 1).

The present oxidation reaction can be readily carried out only by placing a suspension of urazoles (**1**) or bis-

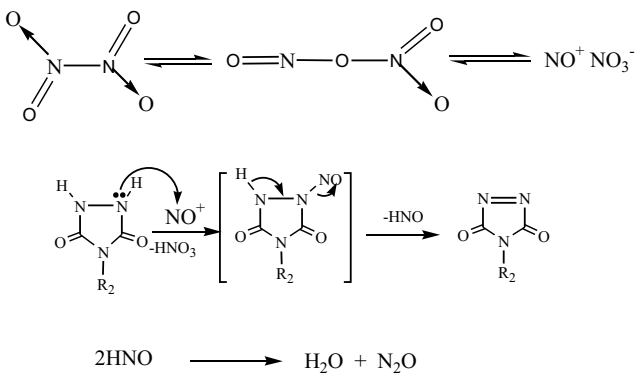
Table 1. Oxidation of urazoles (**1**) and bis-urazoles (**3**) to their corresponding triazolinediones (**2**, **4**) with **PEG-N_2O_4** in dichloromethane at room temperature[a]

Entry	Urazole or (bis)	Time (Min)	Yield[b] %	Product
1	**1a**	30	78	**2a**
2	**1b**	30	80	**2b**
3	**1c**	30	84	**2c**
4	**1d**	30	87	**2d**
5	**1e**	30	90	**2e**
6	**1f**	30	95	**2f**
7	**1g**	30	97	**2g**
8	**1h**	30	85	**2h**
9	**1i**	30	90	**2i**
10	**1j**	30	85	**2j**
11	**1k**	60	82	**2k**
12	**1l**	60	81	**2l**
13	**3a**	40	82	**4a**

[a] Urazole or bis-urazole (1 mmol), **PEG-N_2O_4** (1 mmol).
[b] Isolated yields.

urazoles (**3**), **PEG-N_2O_4** in CH_2Cl_2 and efficiently stirring the resulting heterogeneous mixture at room temperature. The triazolinediones (**2**) and bis-triazolinediones (**4**) are obtained by simple filtration and evaporation of the solvent. As reported above the oxidation reactions are heterogeneous because urazoles and bis-urazoles [(**1, 3**) as white solids] are insoluble in dichloromethane, whereas all of the triazolinediones and bis-triazolinediones [(**2, 4**), red, pink or brown solids] are very soluble in dichloromethane. The **PEG-N_2O_4** in CH_2Cl_2 can act as a relatively efficient reagent as a source for the delivery of nitrosonium ion (NO^+) under mild conditions.[5] The following mechanism for the oxidation reaction via *in situ* generation of NO^+ may be suggested (Scheme III).

Scheme III



Aromatization of 1,4-Dihydropyridines

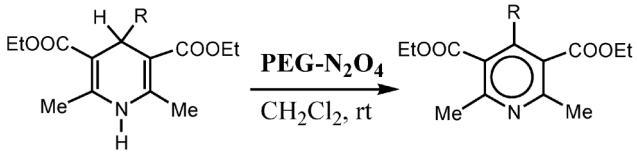
Amlodepine besylate, nifedepine, and related dihydropyridines are Ca^{2+} channel blockers and are rapidly emerging as one of the most important classes of drugs for the treatment of cardiovascular diseases, including hypertension. In the human body, it has been observed that these compounds undergo oxidation to form pyridine derivatives. These oxidized compounds are largely devoid of the pharmacological activity of the parent compounds. Additionally, dihydropyridines are often produced in a synthetic sequence, which have to be oxidized to pyridines.[25]

The oxidation of dihydropyridines (**5**) is an old reaction in general organic chemistry. Even in recent years, several groups have reported new methods for aromatization, including oxidation with ferric or cupric nitrates on a solid support,[26-27] ceric ammonium nitrate,[28] clay-supported cupric nitrate accompanied by ultrasound-promotion,[29] iodine,[30] tetrabutylphosphonium dichromate,[31] photoinduced aromatization,[32] and $KHSO_4$ supported onto Bentonite.[33] Ohsawa et al. reported an excellent procedure for this transformation. They have demonstrated the remarkably practical use of NO gas as a clean and efficient oxidation for this purpose.[34] We decided to seek a completely homogeneous system for dihydropyridine oxidation, and we have investigated a number of different reaction conditions based upon the *in situ* generation of NO^+. In continuation of our study about the applications of NOX,[35] N_2O_4,[23,36] metal nitrate dinitrogen tetroxide complexes[37] and complexation of transition metals with microcyclic ethers,[5] herein we report a simple and convenient method for the effective conversion of 1,4-dihydropyridines (**5**) to their corresponding pyridine derivatives (**6**) by using **PEG-N_2O_4** as an oxidizing agent under mild and homogeneous conditions (Scheme IV).

Different types of dihydropyridines (**5**) were subjected to oxidation reaction in the presence of **PEG-N_2O_4** in dichloromethane (Scheme IV). The oxidation reactions were performed under mild and completely homogeneous conditions at room temperature with good to excellent yields. Aryl-, alkyl-, and heterocyclic-substituted 1,4-dihydropyridines **5d-h** oxidized into the corresponding pyridine derivatives (Table 2).

In addition, we used this reagent for the oxidation of other heterocyclic compounds, such as pyrazoline and oxazoline for example (Scheme V). As shown in Scheme V, both pyrazoline and oxazoline were oxidazed by reacting 1

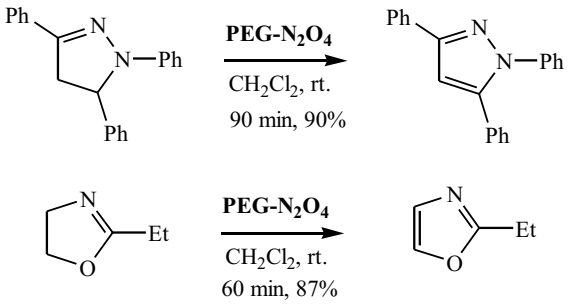
Scheme IV



5 **6**

5, 6	R	5, 6	R
a	H	**e**	3-NO_2-C_6H_5-
b	Me	**f**	2-MeO-C_6H_5-
c	Ph	**g**	2-Furyl-
d	4-NO_2-C_6H_5-		

Scheme V



mmol of these heterocyclic compounds, and **PEG-N_2O_4** (1 mmol) in dichloromethane (5 mL) at room temperature in 60 to 90 min in high yields.

To show the efficiency of the **PEG-N_2O_4** in comparison with older reported procedures in the literature, Table 3 compares some of our results with N_2O_4 gas,[22] [NO^+.crown.$H(NO_3)_2^-$],[5b,c] and NO,[34] with respect to reaction times and yields of obtained products.

Table 2. Aromatization of 1,4-dihydropyridines (**5**), (1 mmol) in the presence of **PEG-N_2O_4** (1 mmol) in dichloromethane at room temperature

Entry	R	Product	Time (Min)	Yield[a] %
1	H	**6a**	60	93
2	Me	**6b**	60	88
3	Ph	**6c**	55	90
4	4-NO_2-C_6H_5	**6d**	55	83
5	3-NO_2-C_6H_5	**6e**	55	86
6	2-MeO-C_6H_5	**6f**	50	93
7	2-Furyl	**6g**	50	82

[a] Isolated yields.

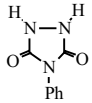
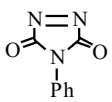
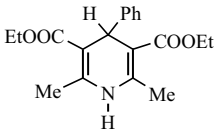
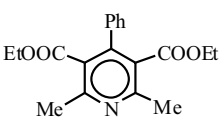
In conclusion, a practical, efficient and convenient method for the oxidation of urazoles, bis-urazoles and 1,4-dihydropyridines is described. We suggest that these systems could be used for the oxidation of a wide variety of urazole derivatives, 1,4-dihydropyridines, and also pyrazoline and oxazolines under mild and safe conditions.

EXPERIMENTAL SECTION

General

Chemicals were purchased from Fluka, Merck and Aldrich chemical companies. Polyethylene glycol 2000 (Mw 1800-2200 g/mol) was purchased from Merck. Yields refer to isolated pure products. The oxidation products were characterized by comparison of their spectral (IR and

Table 3. Comparison of the results **PEG-N_2O_4** (**I**) with N_2O_4 (gas) (**II**),[22] and [NO^+.crown.$H(NO_3)_2^-$] (**III**),[5b] in the oxidation of urazoles and **PEG-N_2O_4** (**I**) with [NO^+.crown.$H(NO_3)_2^-$] (**III**),[5c] and NO (**IV**)[34] in the oxidation 1,4-hydropyridines

Entry	Substrate	Product	Time (Min)				Yield[a] %			
			I	II	III	IV	I	II	III	IV
1			30	90	imid.	-	95	94	-	-
2			55	-	imid.	240	90	-	-	76

[a] Isolated yields.

^{1}H-NMR) and physical data with those of authentic samples which were produced by other reported procedures.[5b,24,34-40]

Caution: NO_2-N_2O_4 gas is exceedingly toxic. Thus, all operations, involving N_2O_4 must be conducted in an efficient hood.

Preparation of polyethyleneglycol-N_2O_4

Into a 250-mL one necked round-bottomed flask was charged 45.0 g of lead(II) nitrate. (The lead(II) nitrate had been crushed to a fine powder with mortar and pestle and then dried in an oven at 120 ºC for three days). The flask was equipped with a 35-cm column and was connected to a trap through a polyethylene tube.[22] The trap was connected to the gas inlet tube.

The lead(II) nitrate was heated with a bunsen burner. Brownish red NO_2-N_2O_4 gas evolved, and it was bubbled slowly through the cold polyethylene glycol (10.0 g) in methylene chloride solution (25 mL) for 30 min. After a few minutes, a deep-red color appeared. The temperature was kept below 0 ºC. The red solution was allowed to stir another 60 min, and then dry N_2 gas was bubbled through the solution in order to extrude the excess of NO_2 gas and then the solvent was evaporated. The obtained solid was dried under vacuum to give PEG supported N_2O_4 as white cream powder (14.0 g). The capacity of the reagent was determined to be 2.5 mmol of N_2O_4 per gram of the polymer. The reagent could be stored in the refrigerator for several months without losing its weight or activity.

Oxidation of 4,4′-(4,4′-diphenylmethylene)-bis-urazole (3a) to bis(*p*-3,5-dioxo-1,2,4-triazoline-4-ylphenyl)-methane (4a): A general procedure

A suspension of compound **3a** (0.366 g, 1 mmol) and **PEG-N_2O_4** (0.1 g) were added into CH_2Cl_2 (10 mL) and stirred for the specified time (Table 1). Then the reaction mixture was filtered and washed with CH_2Cl_2 (2 × 10 mL). Dichloromethane was removed by water-bath (40–50 °C)[38] and simple distillation. A good yield of crystalline pink solid (**4a**) Mp 182-185 ºC, and (lit.[21] Mp 185 °C) was obtained.

Oxidation of 4-phenyl urazole (1f) to 4-phenyl-1,2,4-triazoline-3,5-dione (2f): A typical procedure

A suspension of compound **1f** (0.177 g, 1 mmol) and **PEG-N_2O_4** (0.1 g) were added into dichloromethane (10 mL) and the suspension was vigorously stirred for 0.5 h (Table 1, Entry 6). Then the reaction mixture was filtered and washed with CH_2Cl_2 (2 × 10 mL). Dichloromethane was removed by water-bath (40–50 °C)[38] and simple distillation. The yield was 0.1681 g (95%) of crystalline red solid (**2f**), Mp 171-175 °C, (lit.[22] Mp 170-178 °C).

Spectral data

2a: 4-Methyl-1,2,4-triazoline-3,5-dione: pink crystals, mp 97-98 °C, Lit.[18] 98-98.5 °C. ^{1}H NMR (90 MHz, $CDCl_3$): δ ppm 3.26 (s, 3H).

2b: 4-Eethyl-1,2,4-triazoline-3,5-dione: pink crystals, mp 54-55 °C, Lit.[19] 53 °C. ^{1}H NMR (90 MHz, $CDCl_3$): δ ppm 1.32 (t, 3H), 3.69 (q, 2H). ^{13}C NMR ($CDCl_3$): δ ppm 12.710, 36.702, 159.19.

2c: 4-*n*-Propyl-1,2,4-triazoline-3,5-Dione: pink crystals, mp 40-42 °C, Lit.[23] 44 °C. ^{1}H NMR (90 MHz, $CDCl_3$): δ ppm 0.94 (t, 3H), 1.68 (m, 2H), 3.63 (t, 2H). ^{13}C NMR ($CDCl_3$): δ ppm 10.668, 20.598, 42.884, 159.336.

2d: 4-*n*-Butyl-1,2,4-triazoline-3,5-dione: pink crystals, mp 42-43 °C, Lit.[18] 44-44.5 °C. ^{1}H NMR (90 MHz, $CDCl_3$): δ ppm 0.86 (t, 3H), 1.21-1.53 (m, 4H), 3.5 (t, 2H). ^{13}C NMR ($CDCl_3$): δ ppm 36.372, 42.928, 52.572, 64.572, 168.324.

2e: 4-Cycloyl-1,2,4-triazoline-3,5-Dione: pink crystals, mp 95-97 °C, Lit.[18] 95-96 °C. ^{1}H NMR (90 MHz, $CDCl_3$): δ ppm 1.26-1.8 (m, 10H), 3.90 (m, 1H). ^{13}C NMR ($CDCl_3$): δ ppm 24.207, 24.963, 28.729, 53.936, 158.775.

2f: 4-Phenyl-1,2,4-triazoline-3,5-dione: red crystals, mp 171-175 °C, Lit.[22] 170-178 °C. ^{1}H NMR (90 MHz, $CDCl_3$): δ ppm 7.48 (S, 5H). ^{13}C NMR ($CDCl_3$): δ ppm 124.274, 129.611, 129.900, 157.971.

2g: 4-(4-Chloro phenyl)-1,2,4-triazoline-3,5-dione: red crystals, mp 132-135 °C, Lit.[21] 130-132 °C. ^{1}H NMR (90 MHz, $CDCl_3$): δ ppm 7.41 (S, 5H). ^{13}C NMR ($CDCl_3$): δ ppm 125.100, 130.237, 191.466.

2h: 4-(3,4-Dichloro phenyl)-1,2,4-triazoline-3,5-dione: red crystals, mp 111-113 °C, Lit.[39] 113-115 °C. ^{13}C NMR (22.5 MHz, $CDCl_3$): δ ppm 122.809, 123.588, 126.657, 128.783, 131.626, 134.239, 157.121.

2i: 4-(4-Nitro phenyl)-1,2,4-triazoline-3,5-dione: red crystals, mp 125-126 °C, Lit.[18] 128-129 °C. ^{1}H NMR (90 MHz, $CDCl_3$): δ ppm 7.89-8.40 (m, 5H). ^{13}C NMR ($CDCl_3$): δ ppm 124.152, 125.164, 125.478, 193.894.

2j: 4-(4-Methoxyphenyl)-4*H*-1,2,4-triazole-3,5-dione: dark red crystal, Mp 89-93°C, Lit.[40] 89-93 °C, IR (KBr): 2968, 1773, 1515, 1258, 1173 cm^{-1}, ^{1}H NMR (90 MHz, $CDCl_3$): δ 3.85 (s, 3H), 6.97-7.38 (m, 4H).

2k: 4-(4-*tert*-Butylphenyl)-4*H*-1,2,4-triazole-3,5-dione: red crystal, Mp 122-126 ºC, Lit.[40] 122-126 ºC, IR (KBr): 2962, 1788, 1714, 1518, 1407, 1185 cm^{-1}, ^1H NMR (90 MHz, $CDCl_3$): δ 1.28 (s, 9H), δ 7.33 (m, 4H).

2l: 4-(Naphthalen-1-yl)-4*H*-1,2,4-triazole-3,5-dione: brown crystal, Mp 109-111 ºC, Lit.[40] 109-111 ºC, IR (KBr): 2923, 1715, 1417, 770 cm^{-1}, ^1H NMR (90 MHz, $CDCl_3$): δ 6.94-7.83 (m, 7H).

4a: *Bis*(*para*-3,5-dioxo-1,2,4-triazoline-4-eyl-phenyl)methane: pink crystals, mp 180-185 °C (dec), Lit.[39] 185 °C (dec).

General procedure for the aromatization of 1,4-dihydropyridines

To a solution of compound **5** (1 mmol) and CH_2Cl_2 (5 mL), **PEG-N_2O_4** (0.2 mL, 1 mmol) was added and the mixture was stirred for the appropriate time at room temperature (Table 2). After completion of the reaction, the mixture was filtered, and evaporation of the solvent on a rotary evaporator afforded a residue, which was passed through a short pad of silica gel using a mixture of ethyl acetate and *n*-hexane as eluent to afford the highly pure product.

Spectral data

6a: Mp 70-71 ºC, Lit.[33] 70 ºC, IR (KBr): υ (cm^{-1}) = 1725 (C=O); ^1H NMR (90 MHz, $CDCl_3$): δ ppm 1.4 (t, 6H), 2.8 (s, 6H), 4.3 (q, 4H), 8.7 (s, 1H).

6b: Mp Oil, Lit.[33] Oil, IR (KBr): υ (cm^{-1}) = 1725 (C=O); ^1H NMR (90 MHz, $CDCl_3$): δ ppm 1.4 (t, 6H), 2.3 (s, 3H), 2.5 (s, 6H), 4.37 (q, 4H).

6c: Mp 62-64 ºC, Lit.[33] 61 ºC, IR (KBr): υ (cm^{-1}) = 1722 (C=O); ^1H NMR (90 MHz, $CDCl_3$): δ ppm 0.9 (t, 6H), 2.6 (s, 6H), 3.9 (q, 4H), 7.3 (bs, 5H).

6d: Mp 114-115 ºC, Lit.[41] 114-115 ºC, IR (KBr): υ (cm^{-1}) 1724 (C=O), 1552, 1524 (N=O); ^1H NMR (90 MHz, $CDCl_3$): 0.9 (t, 6H), 2.6 (s, 6H), 4.0 (q, 4H), 7.4 (d, 2H), 8.2 (d, 2H).

6e: Mp 61-62 ºC, Lit.[33] 60-62 ºC, IR (KBr): υ (cm^{-1}) = 1725 (C=O); ^1H NMR (90 MHz, $CDCl_3$): δ ppm 1.0 (t, 6H), 2.7 (s, 6H), 4.0 (q, 4H), 7.6-8.19 (m, 4H).

6f: Mp 56-58 ºC, Lit.[35] 56-58 ºC, IR (KBr): υ (cm^{-1}) = 1718 (C=O); ^1H NMR (90 MHz, $CDCl_3$): δ ppm 0.9 (t, 6H), 2.6 (s, 6H), 3.7 (s, 3H), 4.0 (q, 4H), 6.9-7.3 (m, 4H).

6g: Mp 36-37 ºC, Lit.[33] 39-40 ºC, IR (KBr): υ (cm^{-1}) 1724 (C=O), ^1H NMR (90 MHz, $CDCl_3$): 1.2 (t, 6H), 2.5 (s, 6H), 4.2 (q, 4H), 6.4-6.7 (m, 2H), 7.5-7.6 (m, 1H).

ACKNOWLEDGMENT

Financial support for this work by the Research Council of Bu-Ali Sina University, Hamedan, Iran, is gratefully acknowledged.

Received November 26, 2007.

REFERENCES

1. Sherrington, D. C.; Hodge, P. *Synthesis and Separation Using Functional Polymers*; Wiley: New York, 1980.
2. Sherrington, D. C. In *Polymer-supported Synthesis in Chemistry of Wastes Minimisation*; Clark, J. H., Ed.; Blackei Publishers: London, 1995; Chapter 6, pp 141-196.
3. Hodge, P. *Polymer-supported Asymmetric Organic Synthesis in Innovation and Perspectives in Solid Phase Synthesis*; SPCC: UK, 1990; pp 273-292.
4. (a) Shiri, M. *Synlett* **2006**, 1789. (b) Ono, N. *The Nitro Group in Organic Synthesis*; VCH: New York, 2001. (c) Fisher, J. W. *The Chemistry of Dinitrogen Pentoxide in Nitro Compounds*; VCH: New York, 1990.
5. (a) Zolfigol, M. A.; Zebarjadian, M. H.; Chehardoli, G.; Keypour, H.; Salehzadeh, S.; Shamsipur, M. *J. Org. Chem.* **2001**, *66*, 3619. (b) Zolfigol, M. A.; Zebarjadian, M. H.; Chehardoli, G.; Mallakpour, S. E.; Shamsipur, M. *Tetrahedron* **2001**, *57*, 1627. (c) Zolfigol, M. A.; Zebarjadian, M. H.; Sadeghi, M. M.; Mohammadpoor-Baltork, I.; Memarian, H. R.; Shamsipur, M. *Synth. Commun.* **2001**, *31*, 929. (d) Zolfigol, M. A.; Zebarjadian, M. H.; Mohammadpoor-Baltork, I.; Shamsipur, M. *Synth. Commun.* **2002**, *32*, 2803.
6. (a) Iranpoor, N.; Firouzabadi, H.; Pourali, A. *Synthesis* **2003**, 1591. (b) Iranpoor, N.; Firouzabadi, H.; Pourali, A. *Tetrahedron* **2002**, *58*, 5179.
7. (a) Addison, C. C. *Chem. Rev.* **1980**, *80*, 21. (b) Firouzabadi, H.; Iranpoor, N.; Shiri, M. *Tetrahedron Lett.* **2003**, *44*, 8781. (c) Firouzabadi, H.; Iranpoor, N.; Amani, K. *Synthesis* **2003**, 408. (d) Zolfigol, M. A.; Firouzabadi, H.; Iranpoor, N. *Oriental J. Chem*. **1998**, *14*, 369.
8. Iranpoor, N.; Firouzabadi, H.; Pourali, A. *Synlett* **2004**, 347.
9. (a) Zolfigol, M. A.; Mohammadpoor-Baltork, I.; Khazaei, A.; Shiri, M.; Tanbakouchian, Z. *Lett. Org. Chem.* **2005**, *3*, 305. (b) Zolfigol, M. A.; Mohammadpoor-Baltork, I.; Shiri, M. *J. Iran. Chem. Soc.* **2008**, *5*, 90. (c) Iranpoor, N.; Firouzabadi, H.; Heydari, R. *Phosphorus, Sulfur Silicon Relat. Elem.* **2003**, *178*, 1027.
10. (a) Firouzabadi, H.; Iranpoor, N.; Heydari, R. *Synth. Commun*. **2001**, *31*, 2037. (b) Iranpoor, N.; Firouzabadi, H.; Heydari, R. *Synth. Commun*. **2003**, *33*, 703.
11. Zyryanov, G. V.; Rudkevich, D. M. *J. Am. Chem. Soc.* **2004**,

126, 4264.
12. Zhang, Q.; Zhang, S.; Liu, X.; Zhang, J. *Synth. Commun*. **2001**, *31*, 1243.
13. Zhang, Z.; Zhang, Q.; Zhang, S.; Liu, X.; Zhao, G. *Synth. Commun*. **2001**, *31*, 329.
14. Gokel, G. W.; Korzeniowski, S. H. *Macrocyclic Polyether Synthesis*; Springer-Verlag: Heidelberg, 1982.
15. (a) Izatt, R. M.; Pawlak, K.; Bradshaw, J. S.; Burening, R. L. *Chem. Rev.* **1991**, *91*, 1721. (b) Liu, X.; Zhang, Q.; Zhang, S.; Zhang, J. *Org. Prep. Proced. Int.* **2001**, *33*, 87.
16. (a) Chehardoli, G. *Synlett* **2006**, 2154 and references cited therein. (b) Mallakpour, S. E.; Butler, G. B.; Aghabozorg, H.; Palenik, G. J. *Macromolecules* **1985**, *18*, 342.
17. (a) Zolfigol, M. A.; Choghamarani, A. G.; Shahamirian, M.; Safaiee, M.; Mohammadpoor-Baltork, I.; Mallakpour, S. E.; Abdollahi-Alibeik, M. *Tetrahedron Lett*. **2005**, *46*, 5581. (b) Zolfigol, M. A.; Azarifar, D.; Mallakpour, S. E.; Mohammadpoor-Baltork, I.; Forghaniha, A.; Maleki, B.; Abdollahi-Alibeik, M. *Tetrahedron Lett.* **2006**, *47*, 833. (c) Christoforou, A.; Nicolaou, G.; Elemes, Y. *Tetrahedron Lett*. **2006**, *47*, 9211.
18. Stickler, J. C.; Pirkle, W. H. *J. Org. Chem*. **1966**, *31*, 3444.
19. Read, G.; Rechardson, N. R. *J. Chem. Soc., Perkin Trans. 1*, **1996**,167.
20. Arya, V. P.; Shenoy, S. *Indian J. Chem*. **1976**, *14B*, 883.
21. Wamhoff, H.; Wald, K. *Org. Prep. Proced. Int*. **1975**, *7*, 251.
22. Mallakpour, S. E. *J. Chem. Ed*. **1992**, *69*, 238.
23. Mallakpour, S. E.; Zolfigol, M. A. *J. Sci. I. R. Iran* **1993**, *4*, 199.
24. (a) Zolfigol, M. A.; Bagherzadeh, M.; Mallakpour, S. E.; Chehardoli, G.; Choghamarani, A. G.; Kolvari, E.; Koukabi, N. *Catal. Commun.* **2007**, *8*, 256. (b) Bamoniri, A.; Zolfigol, M. A.; Mohammadpoor-Baltork, I.; Mirjalili, B. F. *J. Iran. Chem. Soc*. **2006**, *3*, 85. (c) Niknam, K.; Zolfigol, M. A. *J. Iran. Chem. Soc*. **2006**, *3*, 59. (d) Firouzabadi, H.; Jafari, A. A. *J. Iran. Chem. Soc*. **2005**, *2*, 85. (e) Zolfigol, M. A.; Niknam, K.; Nazari, F. *J. Chin. Chem. Soc*. **2006**, *53*, 669. (f) Niknam, K.; Zolfigol, M. A.; Sadabadi, T.; Nejati, A. *J. Iran. Chem. Soc*. **2006**, *3*, 318. (g) Salehi, P.; Zolfigol, M. A.; Shirini, F.; Baghbanzadeh, M. *Curr. Org. Chem*. **2006**, *10*, 2171. (h) Kolvari, E.; Ghorbani-Choghamarani, A.; Salehi, P.; Shirini, F.; Zolfigol, M. A. *J. Iran. Chem. Soc.* **2007**, *4*, 126. (i) Zolfigol, M. A.; Niknam, K.; Bagherzadeh, M.; Ghorbani-Choghamarani, A.; Koukabi, N.; Hajjami, M.; Kolvari, E. *J. Chin. Chem. Soc*. **2007**, *54*, 1115. (j) Niknam, K.; Zolfigol, M. A.; Shayegh, M.; Zare, R. *J. Chin. Chem. Soc*. **2007**, *54*, 1067. (k) Ghorbani-Vaghei, R.; Zolfigol, M. A.; Moshfeghifar, N.; Koukabi, N.; Chehardoli, G. *J. Chin. Chem. Soc*. **2007**, *54*, 791.
25. (a) Wang, B.; Hu, Y.; Hu, H. *Synth. Commun*. **1999**, *29*, 4193. (b) Chavan, S. P.; Dantale, S. W.; Kalkote, U. R.; Jyothirmai, V. S.; Kharul, R. K. *Synth. Commun*. **1998**, *28*, 2789.
26. Balogh, M.; Hermecz, I.; Meszaros, Z.; Laszlo, P. *Helv. Chem. Acta* **1984**, *67*, 2270.
27. Khadikar, B.; Borkat, S. *Synth. Commun*. **1998**, *28*, 207.
28. Pfister, J. R. *Synthesis* **1990**, 689.
29. Maquestiau, A.; Mayence, A.; Eynde, J. J. V. *Tetrahedron Lett*. **1991**, *32*, 3839.
30. Zeynizadeh, B.; Dilmaghani, K. A.; Roozijoy, A. *J. Chin. Chem. Soc*. **2005**, *52*, 1215.
31. Memarian, H. R.; Mohammadpoor-Baltork, I.; Javahery, M. *J. Chin. Chem. Soc*. **2006**, *53*, 511.
32. Memarian, H. R.; Abdoli-Senejani, M.; Dopp, D. *J. Chin. Chem. Soc*. **2007**, *54*, 131.
33. Heravi, M. M.; Bakhtiari, K.; Oskooie, H. A. *J. Chin. Chem. Soc*. **2007**, *54*, 579.
34. Itoh, T.; Nagata, K.; Matsuya, Y.; Miyazaki, M.; Ohsawa, A. *J. Org. Chem*. **1997**, *62*, 3582.
35. (a) Zolfigol, M. A.; Kiany-Borazjani, M.; Sadeghi, M. M.; Memarian, H. R.; Mohammadpoor-Baltork, I. *Synth. Commun.* **2000**, *30*, 2945. (b) Zolfigol, M. A.; Kiany-Borazjani, M.; Sadeghi, M. M.; Memarian, H. R.; Mohammadpoor-Baltork, I. *J. Chem. Res. (S)* **2000**, 197. (c) Zolfigol, M. A.; Shirini, F.; Choghamarani, A. G.; Mohammadpoor-Baltork, I. *Green Chem.* **2002**, *4*, 562. (d) Zolfigol, M. A.; Shirini, F.; Choghamarani, A. G.; Mohammadpoor-Baltork, I. *Phosphorus, Sulfur Silicon Relat. Elem.* **2003**, *178*, 1709. (e) Niknam, K.; Zolfigol, M. A.; Razavian, S. M.; Mohammadpoor-Baltork, I. *Heterocycles* **2005**, *65*, 657. (f) Zolfigol, M. A.; Bagherzadeh, M.; Niknam, K.; Shirini, F.; Mohammadpoor-Baltork, I.; Choghamarani, A. G.; Baghbanzadeh, M. *J. Iran. Chem. Soc.* **2006**, *3*, 73. (g) Niknam, K.; Zolfigol, M. A.; Rabani, F. *Heterocyclic Commun.* **2006**, *65*, 183. (h) Niknam, K.; Zolfigol, M. A.; Razavian, S. M.; Mohammadpoor-Baltork, I. *J. Heterocyclic Chem.* **2006**, *43*, 199. (i) Zolfigol, M. A.; Salehi, P.; Safaiee, M. *Lett. Org. Chem.* **2006**, *3*, 153.
36. (a) Mallakpour, S. E.; Zolfigol, M. A. *Indian J. Chem.* **1995**, *34B*, 183. (b) Mallakpour, S. E.; Zolfigol, M. A. *Indian J. Chem.* **1998**, *37B*, 1001. (c) Mallakpour, S. E.; Zolfigol, M. A. *Indian J. Chem.* **1999**, *38B*, 777.
37. (a) Firouzabadi, H.; Iranpoor, N.; Zolfigol, M. A. *Synth. Commun.* **1997**, *27*, 3301. (b) Iranpoor, N.; Firouzabadi, H.; Zolfigol, M. A. *Synth. Commun.* **1998**, *28*, 367. (c) Iranpoor, N.; Firouzabadi, H.; Zolfigol, M. A. *Bull. Chem. Soc. Jpn.* **1998**, *71*, 905.
38. These compounds are sensitive to light, heat, alcohols, ethers, transition metals, and any other nucleophiles. Also, they are very volatile so that if the temperature rises over 50

°C in the course of removing of CH_2Cl_2, some TADs are removed with the solvent simultaneously. Therefore, the temperature must be controlled and dichloromethane is the best solvent for the synthesis of this class of compounds.

39. (a) Zolfigol, M. A.; Nassr-Isfahani, H.; Mallakpour, S. E.; Safaiee, M. *Synlett* **2005**, 761. (b) Zolfigol, M. A.; Ghorbani-Vaghei, R.; Mallakpour, S.; Chehardoli, G.; Ghorbani-Choghamarani, A.; Yazdi, A. H. *Synthesis* **2006**, 1631. (c) Zolfigol, M. A.; Bagherzadeh, M.; Mallakpour, S.; Chehardoli, G.; Kolvari, E.; Ghorbani-Choghamarani, A.; Koukabi, N. *Catal. Commun.* **2007**, 256.
40. Zolfigol, M. A.; Chehardoli, G.; Ghaemi, E.; Madrakian, E.; Zare, R.; Azadbakht, T.; Niknam, K.; Mallakpour, S. *Monatsh. Chem.* **2008**, *in press*.
41. Moghadam, M.; Nasr-Esfahani, M.; Tangestaninejad, S.; Mirkhani, V. *Bioorg. Med. Chem. Lett.* **2006**, *16*, 2026.