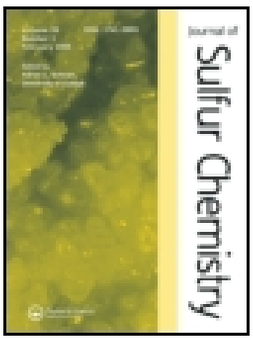


Journal of Sulfur Chemistry

ISSN: 1741-5993 (Print) 1741-6000 (Online) Journal homepage: http://www.tandfonline.com/loi/gsrp20

Silica gel-promoted new one-pot procedure for the synthesis of 1,3-oxathiolan-5-one

Manoj P. Thakare, Rahimullah Shaikh & Dipak Tayade

To cite this article: Manoj P. Thakare, Rahimullah Shaikh & Dipak Tayade (2017): Silica gel-promoted new one-pot procedure for the synthesis of 1,3-oxathiolan-5-one, Journal of Sulfur Chemistry, DOI: 10.1080/17415993.2017.1313256

To link to this article: http://dx.doi.org/10.1080/17415993.2017.1313256

Published online: 12 Apr 2017.

JOURNAL OF SULFUR CHEMISTRY, 2017
http://dx.doi.org/10.1080/17415993.2017.1313256

Taylor & Francis
Taylor & Francis Group

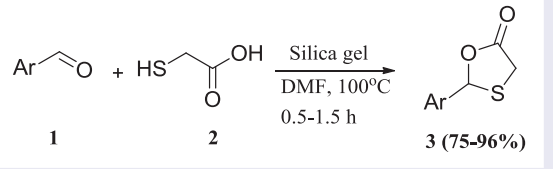
Silica gel-promoted new one-pot procedure for the synthesis of 1,3-oxathiolan-5-one

Manoj P. Thakare, Rahimullah Shaikh and Dipak Tayade

Department of Chemistry, GovernmentVidarbha Institute of Science and Humanities, SantGadge Baba Amravati University, Amravati, India

ABSTRACT

A highly selective two-component silica gel-promoted synthesis of 1,3-oxathiolan-5-one derivatives in N,N-Dimethylformamide (DMF) is presented. The reaction was carried out using aromatic aldehyde and mercaptoacetic acid in the presence of silica gel in DMF with heating. The reactions were worked up by separating the silica gel and recovering the solid product after adding water in excellent yields without any chromatographic purification. Structures of the compounds were satisfactorily confirmed by ^{1}H NMR and LCMS spectral analysis.



ARTICLE HISTORY
Received 28 January 2017
Accepted 27 March 2017

KEYWORDS
1,3-oxathiolan-5-one; silica gel; one-pot synthesis; aldehyde; mercaptoacetic acid

1. Introduction

1,3-Oxathiolan-5-one nucleus-containing heterocyclic compounds are well known for their biological properties and are important heterocyclic compounds occurring in natural and medicinal molecules. They are also the intermediates in the synthesis of many bioactive compounds [1]. The derivatives of 2-(hydroxyl-methyl)- 1,3-oxathiolan-5-ones can be used as building blocks for the preparation of oxathiolanyl-nucleoside containing molecule Coviracil [2–4]. 1,3-Oxathiolanes is one such class of heterocyclic compounds which have attracted much attention as they have been reported to possess a wide range of biological activities, including antiviral [5], anticonvulsant [6], antiulcer [7], and antifungal activity [8]. In addition, they also showed anti-HIV and anti-HBV activity [9], and oxathiolanes act both as agonists [10–12] and antagonists on muscarinic receptors. Cevimeline (*cis*-2-methylspiro [1, 3-oxathiolane-5, 3′-quinuclidine hydrochloride) is a selective M1 receptor agonist. It is also used as fungicides [13], herbicides [14], plant growth regulators

CONTACT Manoj P. Thakare manojorg@rediffmail.com

Supplemental data for this article can be accessed here. http://dx.doi.org/10.1080/17415993.2017.1313256

[15], or enzymes inhibitors [16–18]. 1,3-Oxathiolane have been used as precursors of modified nucleosides, such as the *N*-thioxonucleosides which often present anti-viral activities (Figure 1) [19].

Many methods have been described for the preparation of 1,3-oxathiolan-5-ones as shown in Figure 2. These include one-pot reactions of carbonyl compounds and mercaptoacetic acid with heating in the presence of PTSA [20] or two-step syntheses using $ZnCl_2$ [21] or 2-Methyl-2-phenyl-1,3-oxathiolan-5-ones in the presence of acetophenone and mercaptoacetic acid using LiBr as a catalyst [22]. The synthesis of 1,3-oxathiolan-5-one was also catalyzed by dimethyltin-diiodide-HMPTA complex [23] and molecular iodine in [bmim][BF_4] [24].

In addition, cobalt-doped Zns nanoparticles [25] and $Y(OTf)_3$ [26] have been used for the synthesis of 1,3-oxathiolan-5-ones. Formation of 1,3-oxathiolan-5-ones has been observed as a by-product during the synthesis of thiazolidinones using conventional and/or ultra-sonication methods [27]. Microwave irradiation, for example, was used as an alternative method for the synthesis of 1,3-oxathiolan-5-one [28]. Finally, 1,3-oxathiolan-5-one was also prepared using DCC [29]. 1,3-Oxathiolan-5-one was also synthesized using Mukaiyama reagent in N,N-Dimethylformamide (DMF) at room temperature [30].

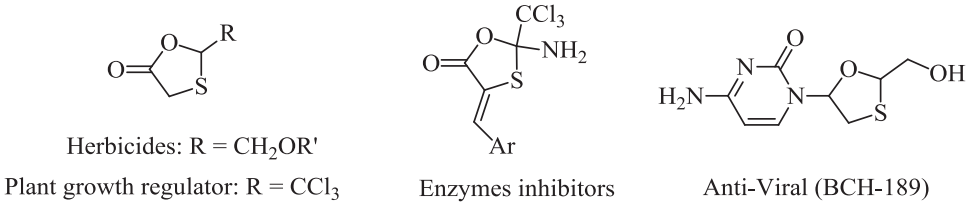


Figure 1. Some biologically important oxathiolane compounds.

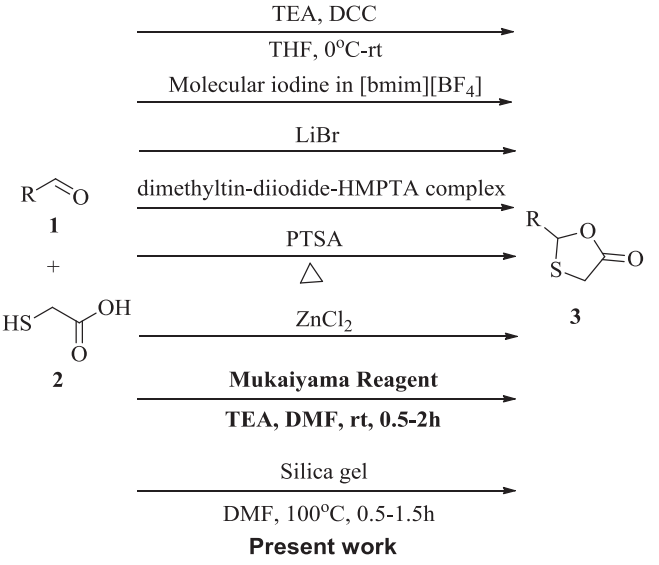


Figure 2. Different methods for the synthesis of 1,3-oxathiolan-5-one derivatives.

Many of the reported methods have limitations, such as long reaction times, difficult workup, and formation of by-products. In addition, others employ harsh reaction conditions, use of expensive and toxic reagents, and explosive reagents like LiBr. In the case of DCC as a dehydrating agent it was difficult to remove the by-product, *i.e.* DCU, without purification. Furthermore, purification of the product required a large amount of volatile solvents. These methods are cumbersome and/or require specialized equipment; therefore, it is important to develop a new simple method which can eliminate these difficulties.

2. Results and discussion

In the initial stages of this study a model reaction was examined using benzaldehyde and mercaptoacetic acid keeping in mind that silica gel may provide assistance in removal of water in the final step of the condensation to afford 1, 3-oxathiolan-5-one. No conversion was observed upon treatment of mercaptoacetic acid and benzaldehyde with silica gel in dichloromethane (DCM) or in DCE at their refluxing temperatures. On the other hand, low yields of product were obtained in refluxing acetonitrile (ACN) and THF. In addition, chromatographic purification was required to obtain the required product. This suggests that DCM, DCE, ACN, or THF are not suitable solvents for the synthesis of 1, 3-oxathiolan-5-one (Table 1).

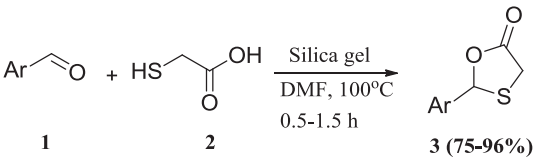
However, reaction yields were excellent when DMF was used as the solvent and no chromatographic purification was required. In the DMF reaction 1.0 mmol of benzaldehyde and 1.0 mmol of mecaptoacetic acid in 5 mL of DMF were stirred continuously for 5 min at room temperature followed by addition of 0.5 g of silica gel. It was then stirred for an additional 1 h at 100°C followed by removal of the silica by filtration. The filtrate was then diluted with ice-cold water and the precipitate collected by filtration and dried under reduced pressure to afford the pure product in 96% yield. This result clearly demonstrates that DMF is far superior to ACN, EtOH, or THF as the solvent for the model reaction. The ready availability, low cost, and the absence of a purification step are advantages that dictate DMF as the solvent of choice for further studies. In addition, the insolubility of the silica gel in the organic solvent facilitates its removal from the reaction mixture (Scheme 1).

After optimization of the reaction conditions we then used these conditions to study different aromatic aldehydes and observed the corresponding products in excellent yields (Table 2). The reactions were very clean at 100°C and completed within 0.5–1.5 h. The

Table 1. Effect of various solvents.[a,b]

Entry	Solvent	Time (h)	Yield (%)
1	DCM	**24**	No Conversion
2	DCE	**24**	No Conversion
3	ACN	**20**	30
4	THF	**10**	32
5	**Ethanol**	**0.8**	**46**
6	DMF(100°C)	0.5	96

[a]Yields are after purification of the compounds.
[b]Confirmed by TLC, ^{1}H NMR and LCMS.



Scheme 1. Proposed approach for the synthesis of 1, 3-oxathiolan-5-one.

proposed reaction mechanism is shown in Scheme 2 and the results obtained mentioned in Table 2.

We think that silica gel can activate the acid group of intermediate **A** with generation of an electron-deficient carbon. This facilitates the intra-molecular addition of hydroxyl to form intermediate **B**. After the loss of water molecule intermediate **B** affords 1, 3-oxathiolan-5-ones (Scheme 2).

3. Conclusion

In this article, we report silica gel as an environment-friendly promoter for the synthesis of 1,3-oxathiolan-5-ones via two-component one-pot condensation of aromatic aldehydes and mercaptoacetic acid. The reactions are quick and no workup is required which makes it a clean and green alternative to other reported procedures (Figure 2). This method avoids the use of toxic, expensive, hazardous chemicals, and provides easy access to pharmaceutically important 1,3-oxathiolan-5-one derivatives in good to excellent yields. At the same time, there is no requirement of any chromatographic purification for the isolation of desired products. As there is no formation of by-products and purification is also not required, this procedure is also useful for the parallel synthesis of a large number of compounds.

4. Experimental

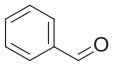
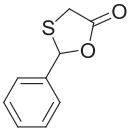
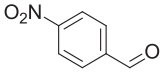
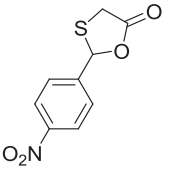
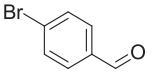
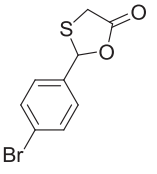
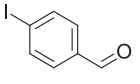
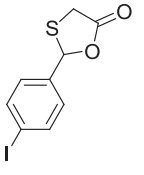
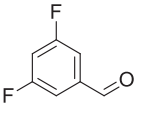
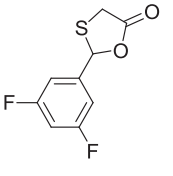
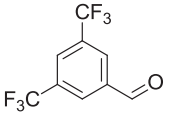
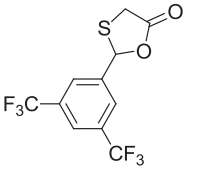
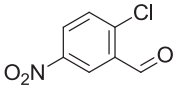
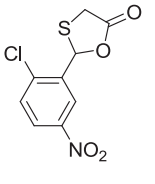
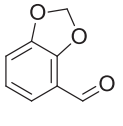
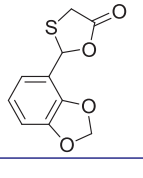
4.1. General remarks

All melting points were uncorrected and were measured using an electro-thermal apparatus. ^{1}H NMR spectra were recorded on Bruker Advance II 400 NMR spectrometer using $CDCl_3$ or DMSO-d_6 as solvents and tetramethylsilane as internal standard and chemical shifts being reported in part per million (δ) relative to TMS. LCMS spectra were obtained using Acquity BEH C-18 column (2.1 × 100 mm, 1.7 µm), and gradient mobile phase consisting of 5 mM ammonium acetate in water and ACN, and a flow rate of 0.5 mL/min. Analytical thin layer chromatography (TLC) was performed on Silica gel $60F_{254}$ (Merck, Germany). The spots were visualized by exposure to UV light at 254 nm and DNP stain.

4.2. General procedure

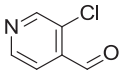
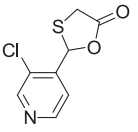
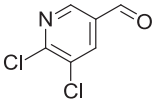
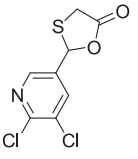
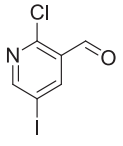
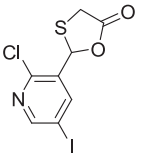
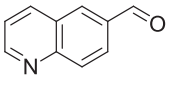
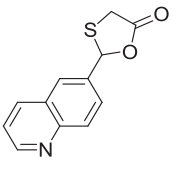
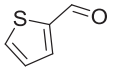
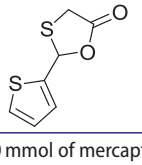
Mercaptoacetic acid (1.0 mmol) was added to a stirred solution of aromatic aldehyde (1.0 mmol) in DMF (5 mL) at room temperature. After 5 min, silica gel (0.5 g) was added to the reaction mixture at room temperature and heated to stir at 100°C. The progress of the

Table 2. Synthesis of 2-aryl-1,3-oxathiolan-5-one using aromatic aldehyde and mercaptoacetic acid in DMF using silica gel.[a,b]

Entry	Aldehyde	Product	Time (h)	Yield (%)[a]
A			1	96[c]
B			1	93[c]
C			0.5	91
D			0.5	92
E			0.5	89
F			1.5	91
G			0.5	90
H			0.5	95

(*continued*).

Table 2. Continued.

Entry	Aldehyde	Product	Time (h)	Yield (%)[a]
I			1.5	85
J			1.5	83
K			1.5	80
L			1.5	82
M			1.5	75

[a]Reaction condition: 1.0 mmol of aromatic aldehyde, 1.0 mmol of mercaptoacetic acid and 0.5 g of silica gel in DMF (5 mL) at 60°C.
[b]Confirmed by TLC, ^{1}H NMR and LCMS.
[c]Ref. [22].

reaction was monitored by thin layer chromatography using *n*-hexane/ethyl acetate (8:2). After completion of the reaction, silica was removed by filtration. The filtrate was diluted with ice water to obtain solid as a product. The crude product was collected by filtration and washed with ice water. The solid was again washed with ice cooled 10% diethyl ether in pentane for the fast removal of traces of water to get crystals and dried under reduced pressure to afford the pure product (**3a**–**m**).

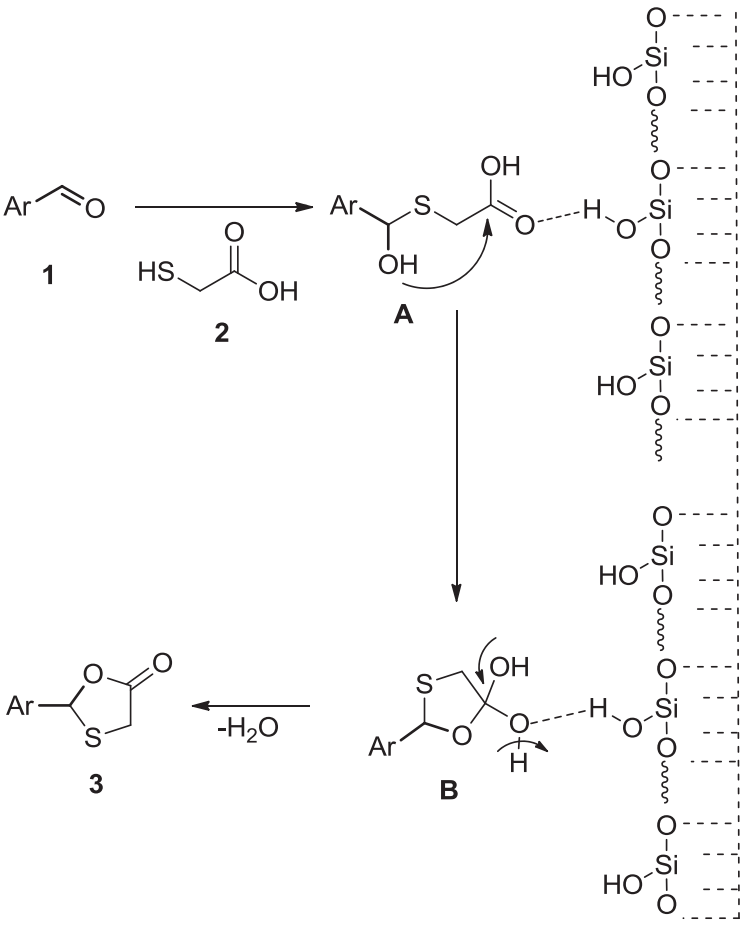
4.3. Analytical data

4.3.1. 2-Phenyl-1,3-oxathiolan-5-one (3a)

White solid, M.P.85–87°C; ^{1}H NMR (400 MHz, $CDCl_3$): 7.40–7.47 (5H, m), 6.47 (1H, s), 3.87 (1H, d, J = 16.4 Hz), 3.76 (1H, d, J = 16.8 Hz). LCMS calcd for $C_9H_8O_2S$ (M^+) 180.91, found 180.91.

4.3.2. 2-(4-Nitrophenyl)-1,3-oxathiolan-5-one (3b)

Yellow solid, M.P. 83–85°C; ^{1}H NMR (400 MHz, $CDCl_3$): 8.27 (2H, d, J = 8.4 Hz), 7.64 (2H, d, J = 8.4 Hz), 6.54 (1H, s), 3.90 (1H, d, J = 16.4 Hz), 3.76 (1H, d, J = 16.4 Hz). LCMS calcd for $C_9H_7NO_4S$ (M^+) 224.01, found 223.99.



Scheme 2. Plausible mechanism for silica gel-promoted synthesis of 1,3-oxathiolan-5-one in DMF.

4.3.3. 2-(4-Bromophenyl)-1, 3-oxathiolan-5-one (3c)

White solid; M.P. 91–93°C;^{1}H NMR (400 MHz; $CDCl_3$): 7.54 (2H, d, J = 8.4 Hz), 7.34 (2H, d, J = 8.4), 6.41 (1H, s), 3.86 (1H, d, J = 16.8), 3.75 (1H, d, J = 16.8); LCMS: m/z [M^+] calculated for $C_9H_7BrO_2S$: 258.94, found: 259.03.

4.3.4. 2-(4-Iodophenyl)-1, 3-oxathiolan-5-one (3d)

White solid; M.P. 93–95°C;^{1}H NMR (400 MHz; $CDCl_3$): 7.75 (2H, d, J = *8.0*), 7.20 (2H, d, J = 8.0), 6.40 (1H, s), 3.86 (1H, d, J = 16.4), 3.75 (1H, d, J = 16.4); LCMS: m/z [M^+] calculated for $C_9H_7IO_2S$: 307.12, found: No ionization.

4.3.5. 2-(3,5-Difluorophenyl)-1,3-oxathiolan-5-one (3e)

White solid; M.P. 99–101°C;^{1}H NMR (400 MHz, DMSO-d_6): 7.26–7.34 (3H, m), 6.69 (1H, s), 4.07 (1H, d, J = 16.4 Hz), 4.00 (1H, d, J = 16.4 Hz). LCMS calcd for $C_9H_6F_2O_2S$ (M^--F) 217.01, found: 197.08.

4.3.6. 2-[3,5-Bis(trifluoromethyl)phenyl]-1,3-oxathiolan-5-one (3f)

Off white solid; M.P. 113–115°C;^{1}H NMR (400 MHz, $CDCl_3$): 7.92 (3H, s), 6.54 (1H, s), 3.93 (1H, d, J = 16.8 Hz), 3.81 (1H, d, J = 16.8 Hz). LCMS calcd for $C_{11}H_6F_6O_2S$ (M^+) 315.22, found 314.96.

4.3.7. 2-(2-Chloro-5-nitrophenyl)-1,3-oxathiolan-5-one (3g)

White solid; M.P. 96–97°C;^{1}H NMR (400 MHz, DMSO-d_6): 8.28 (2H, s), 7.87 (1H,d, J = 8.4 Hz), 6.99 (1H, s), 4.10 (1H, d, J = 16.4 Hz), 4.03 (1H, d, J = 16.4 Hz). LCMS calcd for $C_9H_6ClNO_4S$ (M^+) 259.97, found No ionization.

4.3.8. 2-(Benzo[d][1, 3]dioxol-4-yl)-1,3-oxathiolan-5-one (3h)

White solid; M.P. 103–106°C;^{1}H NMR (400 MHz, CDCl3): 6.84–6.90 (3H, m), 6.53 (1H, s), 6.03 (2H, s), 3.79–3.85 (2H, m). LCMS calcd for $C_{10}H_8O_4S$ (M^+) 225.23, found 225.00.

4.3.9. 2-(3-chloropyridin-4-yl)-1,3-oxathiolan-5-one (3i)

Light brown solid; M.P. 180–182°C;^{1}H NMR (400 MHz, DMSO-d_6): 8.71 (1H, s), 8.62 (1H,s), 7.52 (1H, s), 6.90 (1H, s), 4.09 (1H, d, J = 16.4 Hz),3.98 (1H, d, J = 16.4 Hz). LCMS calcd for $C_8H_6ClO_2S$ (M^+) 216.66, found 216.07.

4.3.10. 2-(5,6-dichloropyridin-3-yl)-1,3-oxathiolan-5-one (3j)

White solid; M.P. 181–184°C;^{1}H NMR (400 MHz; DMSO-d_6) 8.54 (1H, s), 8.35 (1H, s), 6.74 (1H, s), 4.01–4.10 (2H, m); LCMS: calcd for $C_8H_5Cl_2NO_2S$: 249.94, found: 249.86.

4.3.11. 2-(2-chloro-5-iodopyridin-3-yl)-1,3-oxathiolan-5-one (3k)

Black oil; M.P. 183–185°C;^{1}H NMR (400 MHz, DMSO-d_6): 8.07 (1H, s), 8.06 (1H, s), 7.12 (1H, s), 4.17 (1H, d, J = 16.4 Hz), 4.02 (1H, d, J = 16.4 Hz). LCMS calcd for $C_8H_5ClNO_2S$ (M^+) 341.88, found 342.08.

4.3.12. 2-(quinolin-6-yl)-1,3-oxathiolan-5-one (3l)

Off white solid; M.P. 130–132°C;^{1}H NMR (400 MHz, DMSO-d_6): 8.95 (1H, s),8.44 (1H, d, J = 8.0 Hz), 8.12 (1H, s), 8.09 (1H, d, J = 8.8 Hz), 7.86 (1H, d, J = 8.8 Hz), 7.57–7.60 (1H, m), 6.91 (1H, s), 4.14 (1H, d, J = 16.4 Hz), 4.02 (1H, d, J = 14.4 Hz). LCMS calcd for $C_{12}H_9NO_2S$ (M^+) 232.04, found 232.13.

4.3.13. 2-(thiophen-2-yl)-1,3-oxathiolan-5-one (3m)

Brown oil; ^{1}H NMR (400 MHz, DMSO-d_6): 7.43 (1H, d, J = 4.8 Hz), 7.32 (1H, d, J = 3.2 Hz), 7.01–7.03 (1H, m), 6.67 (1H, s), 3.78–3.88 (2H, m). LCMS calcd for $C_7H_6O_2S_2$ (M^+) 187.25, found 187.17.

Acknowledgements

We are thankful to the Head, Department of Chemistry, for his continuous support and guidance throughout the work.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

[1] Popp A, Gilch A, Mersier AL, et al. Enzymatic kinetic resolution of 1,3-dioxolan-4-one and 1,3-oxathiolan-5-one derivatives: synthesis of the key intermediate in the industrial synthesis of the nucleoside reverse transcriptase inhibitor AMDOXOVIR. Adv Synth Catal. 2004;346:682–690.

[2] Choi WS, Wilson LJ, Yeola S, et al. In situ complexation directs the stereochemistry of N-glycosylation in the synthesis of thialanyl and dioxolanyl nucleoside analogs. J Am Chem Soc. 1991;113(24):9377–9379.

[3] Lotta DC, Schinazi RF, Choi WS. Antiviral activity and resolution of 2-hydroxymethyl-5-(5-fluorocytosin-1-yl)-1,3-oxathiolane. Chem Abstr. 1993;118:22551. Emory University, USA, WO 9214743 A2; 1992.

[4] Lotta DC, Choi WS. Method and compositions for the synthesis of BCH-189 and related compounds. Chem Abstr. 1991;115:208463. Emory University, USA, WO 9111186 A1; 1991.

[5] Nguyen BN, Lee N, Chan L, et al. Synthesis and antiviral activities of *N*-9-oxypurine 1,3-Dioxolane and 1,3-oxathiolane nucleosides. Bioorg Med Chem Lett. 2000;10:2223–2226.

[6] Rajopadhye M, Popp FD. Potential anticonvulsants. 11. Synthesis and anticonvulsant activity of spiro[1,3-dioxolane-2,3′-indolin]-2′-ones and structural analogs. J Med Chem. 1988;31:1001–1005.

[7] Aloup JC, Bouchaudon J, Farge D, et al. Synthesis and antisecretory and antiulcer activities of derivatives and analogs of 2-(2-pyridyl) tetrahydrothiophene-2-carbothioamide. J Med Chem. 1987;30:24–29.

[8] Miyauchi H, Tanio T, Ohashi N. Synthesis and antifungal activity of new azole derivatives containing an oxathiane ring. Bioorg Med Chem Lett. 1996;6:2377–2380.

[9] Nokami J, Ryokume K, Inada J. Synthesis of 1,3-oxathiolane derivatives as novel precursors of 2′,3′-dideoxy-3′-oxa-4′-thioribonucleosides. Tetrahedron Lett. 1995;36:6099–6100.

[10] Fisher A, Brandeis R, Pittel Z, et al. (±)-*cis*-2-Methyl-spiro(1,3-oxathiolane-5,3′) quinuclidine (AF102B): a new M_1 agonist attenuates cognitive dysfunctions in AF64A-treated rats. Neurosci Lett. 1989;102:325–331.

[11] Dei S, Bellucci C, Muccioni M, et al. Muscarinic antagonists with multiple stereocenters: synthesis, affinity profile and functional activity of isomeric 1-methyl-2-(2,2-alkylaryl-1,3-oxathiolan-5-yl)pyrrolidinesulfoxide derivatives. Bioorg Med Chem. 2008;16:5490–5500.

[12] Angeli P, Brasili L, Gianella M, et al. Chiral muscarinic agonists possessing a 1,3-oxathiolane nucleus: enantio- and tissue-selectivity on isolated preparations of guinea-pig ileum and atria and of rat urinary bladder. Naunyn-Schmiedeberg's Arch Pharmacol. 1988;337:241–245.

[13] Vladimirskay EV, Novikevich OT, Demchuk OG. The synthesis of a novel 4,4-difluoro-1,3-oxathiolanone. Farm Zh. 1991;6:67. Chem Abstr. 1992;116:194218.

[14] Pilgram KHG. Herbicidal heterocyclic compounds. Chem. Abstr. 1977;87:53263. US Pat. Appl. US 4019892; 1977.

[15] Krumkalna EV. Methods for plants growth regulation. Chem Abstr. 1981;95:163901. US Pat. Appl. US 4282030; 1981.

[16] Ead HA, Abdelazizz MA, Metawalli NH. Pol. J. Chem. 1991;65:1291.

[17] Higashiya S, Narizuka S, Konno A, et al. Electrolytic partial fluorination of organic compounds. 30.1 drastic improvement of anodic monofluorination of 2-substituted 1,3-oxathiolan-5-ones using the novel fluorine source $Et_4NF{\cdot}4HF$. J Org Chem. 1999;64:133–137.

[18] Ogawa K, Yamada S, Terada T, et al. Syntheses of novel 1,3-Oxathiolan-5-one derivatives. Synthesis (Mass). 1984;1984:595–597.

[19] Yokoyama H. Synthesis and biological activity of thionucleosides. Synthesis (Mass). 2000;1637–1655.

[20] Uang BJ, Po SY, Hung SC, et al. Asymmetric synthesis employing chiral ketones as templates. Pure Appl Chem. 1997;69:615–620.

[21] Pustovit YM, Alekseenko AN, Subota AI, et al. Convenient method for synthesis of 2-trifluoromethyl-1,3-oxathiolan-5-ones. Chem Heterocyclic Compd. 2006;42:278–279.

[22] Yadav LDS, Yadav S, Rai VK. A highly efficient green catalytic system for one-pot synthesis of 1,3–oxathiolanes. Tetrahedron 2005;61:10013–10017.

[23] Shibata I, Baba A, Iwaski H, et al. Cycloaddition reaction of heterocumulenes with oxiranes catalyzed by organotin iodide-lewis base complex. J Org Chem. 1986;51:2177–2184.
[24] Dewan M, Kumar A, Saxena A, et al. Molecular iodine in [bmim][BF_4]: a highly efficient green catalytic system for one-pot synthesis of 1,3-oxathiolan-5-one. Tetrahedron Lett. 2010;51:6108–6110.
[25] Dandia A, Parewa V, Gupta SL, et al. Cobalt doped Zns nanoparticles as a recyclable catalyst for solvent-free synthesis of heterocyclic privileged medicinal scaffolds under infrared irradiation. J Mol Catal. 2013;373:61–71.
[26] Luo J, Zhong Z, Ji H, et al. A facile and effective procedure for the synthesis of 4-thiazolidinone derivatives using $Y(OTf)_3$ as catalyst. J Sulfur Chem. 2016;37:438–449.
[27] Reddy PR, Padmaja A, Padmavathi V. Synthesis of heteroarylthiazolidinones and azetidinones under conventional and ultrasonicationmethods. J Heterocyclic Chem. 2015;52:1474–1482.
[28] Cunico W, Vellasco WT, Moreth M, et al. Microwave-assisted synthesis of 1,3-thiazolidin-4-ones and 2-aryl-1,3-oxathiolan-5-ones. Lett Org Chem. 2008;5:349–352.
[29] Kashyap DK, Kushwaha ND, Sharma R, et al. A facile and one highly efficient synthesis of 1,3-oxathiolan-5-one derivatives. J Indian Chem Soc. 2015;92:1–4.
[30] Thakare MP, Shaikh R. Mukaiyama reagent: novel one-pot system for the synthesis of 1,3-oxathiolan-5-one. Res J Chem Sci. 2016;6:8–12.