Available online at www.sciencedirect.com

SciVerse ScienceDirect

Chinese Chemical Letters 23 (2012) 1035–1038

CHINESE CHEMICAL LETTERS

www.elsevier.com/locate/cclet

A simple and effective approach to the synthesis of alkynyl selenides from terminal alkynes

Barahman Movassagh *, Mozhgan Navidi

Department of Chemistry, K.N. Toosi University of Technology, P.O. Box 16315-1618, Tehran, Iran

Received 16 May 2012
Available online 18 July 2012

Abstract

Alkynyl selenides were prepared under very mild conditions by reacting terminal alkynes with respective diorganic diselenides in the presence of potassium *t*-butoxide. The advantages of this protocol include the use of readily available substrates and reagent and good yield of the products.

Keywords: Alkynyl selenides; Diorganic diselenides; Potassium *t*-butoxide; Terminal alkynes; Phenyl acetylene

The impact of organoselenium chemistry on modern organic synthesis is undisputable [1]. Over the last three decades many researchers have investigated important chemical transformations that were efficiently achieved using organoselenium reagents. The chemistry of organoselenium compounds has been of growing interest because of their involvement as key intermediates in organic synthesis and use as a food supplement [2].

Organoselenium compounds have also pivotal role in the synthesis of a large number of biological compounds (e.g. selenopeptides, selenoamino acids, selenocarbohydrates). These compounds are also promising pharmacological agents in view of their antioxidant, antitumor, antimicrobial, and antiviral properties [3].

Among various organoselenium compounds, alkynyl selenides play an important role in organic synthesis by serving as crucial synthons in the transformations of a wide range of functional groups with a high degree of selectivity [4,5]. Alkynyl selenides can be transformed into substituted olefins by chlorocarbonylation, hydrosulfonation, hydrohalogenation, hydrostannylation, hydrozirconation, and hydroboration reactions [6]. In addition, they can act as excellent Diels-Alder dienophiles [7] and as inhibitors of oxidative enzymes such as δ-aminolevulinate dehydratase [8]. Very recently, a new palladium-catalyzed reaction of alkynyl selenides with acetylenedicarboxylates leading to alkynylvinyl selenides and multisubstituted aryl selenides, via an intermolecular [2 + 2 + 2] cycloaddition reaction have been developed [9]. Consequently, a number of methodologies have been developed for the synthesis of these compounds [4b]. In general, the methods for the preparation of alkynyl selenides include (a) metal-assisted cross-coupling with either Mg or Cu salts [6a,10,11], (b) reaction of alkynyl organometallics with organoselenenyl halide (RSeX) or diorgano diselenides (RSeSeR) [12], (c) intramolecular Wittig reaction of α-acyl-α-seleno phosphoranes [13], (d) seleno functionalization of alkynes [14], (e) reaction of (potentially explosive) bromoalkynes with selenolates

* Corresponding author.
E-mail address: bmovass1178@yahoo.com (B. Movassagh).

1001-8417/$ – see front matter
http://dx.doi.org/10.1016/j.cclet.2012.06.036

or diselenides [12c,15], and (f) coupling of terminal acetylenes to phenylselenenyl bromide in the presence of $CsOH{\cdot}H_2O$ [16]. As a drawback, most of these synthetic protocols elaborated upon above suffer from various disadvantages such as long reaction times, low temperatures, use of air and moisture sensitive and expensive reagents, and the use of hazardous and toxic reagents or organic solvents. Taking into account these constraints, we were motivated to investigate the development of a mild, more convenient, and efficient reaction condition for the synthesis of alkynyl selenides which circumvented these common impediments. In a recent report, Xu et al. [17] prepared alkynyl selenides from the reaction of diselenides with terminal alkynes catalyzed by CsOH.

1. Experimental

Melting points were recorded on a Buchi B-540 apparatus and are uncorrected. IR spectra were recorded on an ABB FTLA 2000 instrument. NMR spectra were recorded with either a Bruker AQS-300 spectrometer with nominal frequency of 300 MHz for proton or 75 MHz for carbon, respectively in $CDCl_3$ using TMS as an internal standard.

1.1. General procedure

A mixture of terminal alkyne (1.0 mmol), *t*-BuOK (0.134 g, 1.2 mmol), and DMF (1 mL) was placed in a test tube. The reaction mixture was magnetically stirred at 25 °C for about 15 min; then diselenide (0.5 mmol) was added at once to the above mixture, and stirring was continued at that temperature for the appropriate time (Table 1) in air atmosphere. The progress of the reaction was monitored by TLC. After completion of the reaction, the solution was filtered and the solvent was evaporated under reduced pressure, EtOAc (8 mL) was added, and the mixture washed with H_2O (3×6 mL). The organic layer was dried (Na_2SO_4), and concentrated. The resulting crude product was purified by preparative TLC (Silica, eluent, *n*-hexane:EtOAc = 9:1) to afford the desired product. All compounds are known, and were identified by comparison of their spectral data with those reported in the literature. Selected data: 4-chlorophenyl-4-tolylethynyl selenide **(3d)**: Yellow crystals; mp: 49–51 °C; IR (KBr, cm^{-1}): 2161; ^1H NMR (300 MHz, $CDCl_3$): δ 7.52 (d, 2H, $J = 8.6$ Hz), 7.41 (d, 2H, $J = 7.9$ Hz), 7.30 (d, 2H, $J = 8.6$ Hz), 7.16 (d, 2H, $J = 7.9$ Hz), 2.37 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 139.1, 134.6, 132.2, 131.8, 130.2, 129.6, 129.2, 127.1, 103.6, 67.5, 21.6. Phenyl-1-hexynyl selenide **(3i)**: Light yellow oil; IR (neat, cm^{-1}): 2177; ^1H NMR (300 MHz, $CDCl_3$): δ 7.59–7.54 (m, 2H), 7.33–7.24 (m, 3H), 2.30 (t, 2H, $J = 7.0$ Hz), 1.48 (quin, 2H, $J = 7.5$ Hz), 1.26 (sext, 2H, $J = 7.2$ Hz), 0.83 (t, 3H, $J = 7.3$ Hz); ^{13}C NMR (75 MHz, $CDCl_3$): δ 136.3, 132.8, 132.6, 129.2, 104.7, 57.3, 39.6, 31.1, 21.9, 13.8.

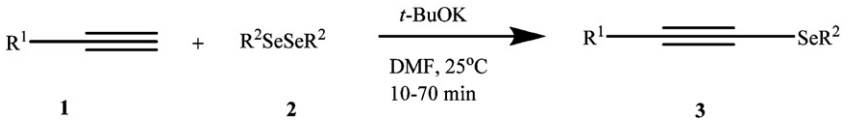
2. Results and discussion

In this letter, we present our contribution to the field by developing a mild protocol for the synthesis of alkynyl selenides via the reaction of terminal alkynes with various diselenides at room temperature in an aerial atmosphere in

Table 1
Alkynyl selenide formation in the presence of *t*-BuOK.

Entry	R^1	R^2	Product	Time (min)	Yield[a,b] (%)
1	Ph	Ph	**3a**	10	82 [15b]
2	Ph	4-MeC_6H_4	**3b**	15	66 [15b]
3	Ph	4-ClC_6H_4	**3c**	45	70 [12e]
4	4-MeC_6H_4	4-ClC_6H_4	**3d**	40	65 [12e]
5	4-MeC_6H_4	4-MeC_6H_4	**3e**	15	64 [20]
6	4-ClC_6H_4	4-MeC_6H_4	**3f**	25	60 [11a]
7	4-ClC_6H_4	Ph	**3g**	60	61 [15b]
8	4-BrC_6H_4	Ph	**3h**	50	58 [11c]
9	*n*-C_4H_9	Ph	**3i**	70	47 [14]
10	*n*-C_6H_{13}	Ph	**3j**	120	53 [21]

[a] Isolated yields.
[b] References for the known compounds.



Scheme 1.

the presence of potassium *t*-butoxide as a base. The alkoxide-promoted addition of terminal alkynes to ketones [18] and aziridines [19] has been reported in recent years.

The experiments were initially conducted with phenylacetylene and diphenyl diselenide, as a model reaction, at various molar ratios, solvents, and temperatures under an aerial atmosphere. The best molar ratios of phenylacetylene: diphenyl diselenide: potassium *t*-butoxide was found to be 1:0.5:1.2. Regarding the influence of the solvent and temperature, better results were achieved using dry DMF at 25 °C, which furnished the desired selenoalkyne, after purification, in 82% yield after 10 min. To demonstrate the efficiency of this reaction, we explored the generality of our method, extending the conditions to other alkynes and different diselenides (Scheme 1) and the results are summarized in Table 1.

As clear from the table, the reactions proceeded to provide moderate to good yield of alkynyl selenides (**3**) with varied substrates within a short time (10–70 min). We found that this method is applicable for aromatic as well as aliphatic alkynes and different diaryl diselenides. Reaction of aliphatic alkynes, 1-hexyne and 1-octyne, with diphenyl diselenide (entries 9 and 10, Table 1) took long times (70 and 120 min, respectively) giving the products (**3i** and **3j**) with 47 and 53% yields respectively. The structures of all the products were established from their analytical and spectral (IR, ^{1}H and ^{13}C NMR) properties. It is noteworthy that solid potassium *t*-butoxide is inexpensive and commercially available.

To conclude, we have developed a simple, general, mild and efficient procedure for the synthesis of alkynyl selenides in good yields using readily available substrates and reagents. Our method has the advantages of operational simplicity, mild reaction conditions, fast reaction rates, and simple reaction work-up.

Acknowledgment

The authors thank the K.N. Toosi University of Technology Research Council for financial assistance.

References

[1] (a) T.G. Back, Organoselenium Chemistry: A Practical Approach, Oxford University Press, Oxford, 1999;
(b) D. Liotta, Organoselenium Chemistry, Wiley, New York, 1987.
[2] (a) A. Krief, L. Hevesi, Organoselenium Chemistry, vol. 1, Springer, Berlin, 1988;
(b) A. Krief, in: B.M. Trost (Ed.), Comprehensive Organometallic Chemistry, Pergamon, Oxford, 1991, p. 85.
[3] M.A. Lucas, O.T.K. Ngugen, C.H. Schiesser, et al. Tetrahedron 56 (2000) 3995.
[4] Reviews:
(a) T. Wirth, Angew. Chem. Int. Ed. 39 (2000) 3740;
(b) J.V. Comasseto, L.W. Ling, N. Petragnani, et al. Synthesis (1997) 373, and references cited therein.
[5] A. Chieffi, J.V. Comasseto, in: T.G. Back (Ed.), Organoselenium Chemistry: A Practical Approach, Oxford University Press, UK, 1999, pp. 131–135.
[6] (a) X. Huang, Y. Ma, Synthesis (1997) 417;
(b) D.Y. Yang, X. Huang, J. Organomet. Chem. 543 (1997) 165;
(c) M. Tingoli, M. Tiecco, L. Testaferri, et al. Tetrahedron 51 (1995) 4691;
(d) A. Sun, X. Huang, Synthesis (2000) 775;
(e) M.J. Dabdoub, M.L. Begnini, P.G. Guerrero, et al. J. Org. Chem. 65 (2000) 61;
(f) M.I. Al-Hassan, Synth. Commun. 31 (2001) 3027;
(g) L.S. Zhu, Z.Z. Huang, X.J. Huang, J. Chem. Res. (S) (1996) 112.
[7] (a) Y. Ma, C. Qian, Tetrahedron Lett. 41 (2000) 945;
(b) W.M. Xu, E. Tang, X. Huang, Tetrahedron 61 (2005) 501.
[8] R.C. Bolzan, V. Folmer, M. Farina, et al. Pharmacol. Toxicol. 90 (2002) 214.
[9] T. Mitamura, A. Ogawa, Tetrahedron Lett. 51 (2010) 3538.
[10] J.V. Comasseto, P.H. Menezes, H.A. Stefani, et al. Tetrahedron 52 (1996) 9687.

[11] (a) J.P. Das, S. Roy, Organometallics 24 (2005) 6136;
(b) A. Kundu, S. Roy, Organometallics 19 (2000) 105;
(c) A.L. Braga, C.C. Silveira, A. Reckziegel, et al. Tetrahedron Lett. 34 (1993) 8041.
[12] (a) G.W. Kabalka, B. Venkataiah, Tetrahedron Lett. 43 (2002) 3703;
(b) X. Huang, L.S. Zhu, Synth. Commun. 26 (1996) 671;
(c) H. Lang, H. Keller, W. Imhof, et al. Chem. Ber. 123 (1990) 417;
(d) X. Huang, L.S. Zhu, J. Organomet. Chem. 523 (1996) 9;
(e) D.J. Cook, A.F. Hill, D.J. Wilson, J. Chem. Soc. Dalton Trans. (1998) 1171.
[13] A.L. Braga, J.V. Comasseto, N. Petragnani, Synthesis (1984) 240.
[14] L.W. Bieber, M.F. da Silva, P.H. Menezes, Tetrahedron Lett. 45 (2004) 2735.
[15] (a) A.L. Braga, A. Reckziegel, P.H. Menezes, et al. Tetrahedron Lett. 34 (1993) 393;
(b) A. Sharma, R.S. Schwab, A.L. Braga, et al. Tetrahedron Lett. 49 (2008) 5172.
[16] R.J. Cohen, D.L. Fox, R.N. Salvatore, J. Org. Chem. 69 (2004) 4265.
[17] X.H. Xu, R.L. Lu, Q.L. Zhang, et al. Chem. J. Chin. Univ. 26 (2005) 267.
[18] (a) H. Miyamoto, S. Yasaka, K. Tanaka, Bull. Chem. Soc. Jpn. 74 (2001) 185;
(b) J.H. Babler, V.P. Liptak, N. Phan, J. Org. Chem. 61 (1996) 416.
[19] C.H. Ding, L.X. Dai, X.L. Hou, Tetrahedron 61 (2005) 9586.
[20] L.M. Kataeva, N.S. Padkovyrina, T.G. Mannafov, et al. Zh. Fiz. Khim. 47 (1973) 29 (Chem. Abst. 80 (1974) 36566e).
[21] P.G. Guerrero, M.J. Dabdoub, A.C.M. Baroni, Tetrahedron Lett. 49 (2008) 3872.