



Facile generation of *vicinal* bromoazides from olefins using TMSN_3 and TsNBr_2 without any catalyst

Indranirekha Saikia, Prodeep Phukan *

Department of Chemistry, Gauhati University, Guwahati 781 014, Assam, India

ARTICLE INFO

Article history:

Received 3 April 2009

Revised 11 June 2009

Accepted 12 June 2009

Available online 16 June 2009

Keywords:

Bromoazidation

Trimethylsilyl azide (TMSN_3)

N,N-Dibromo-*p*-toluenesulfonamide

(TsNBr_2)

Bromoazide

Olefin

α,β -Unsaturated carbonyl compounds

Acrylates

Styrene

ABSTRACT

A very rapid and efficient method has been developed for the synthesis of *vicinal* bromoazides directly from olefin using *N,N*-dibromo-*p*-toluenesulfonamide (TsNBr_2) without any catalyst. The reaction is extremely fast which goes into completion instantaneously to produce bromoazides. This procedure is applicable to various olefins such as cinnamates, chalcone, styrenes, and acrylate to give the corresponding 1,2-bromoazide in an excellent yield.

© 2009 Elsevier Ltd. All rights reserved.

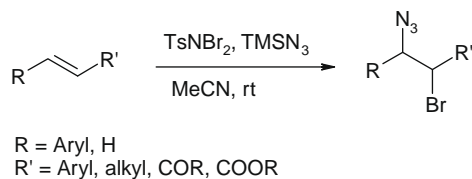
Organic azides are versatile building blocks with a diverse range of applications in organic chemistry,¹ with a use as intermediates for the construction of synthetically and biologically important compounds such as amines² and heterocycles.³ In recent past, azido compounds have also been gaining importance as the key intermediates in the emerging field of 'click chemistry'.⁴ Haloazidation is an important organic transformation for simultaneous introduction of halogen and azide functionality onto an olefin. The resulting haloazides can be subjected to further synthetic manipulations to achieve a variety of compounds such as vinyl azide,⁵ amines,⁶ aziridins,⁷ and tetrazoles.⁸ Vicinal iodoazidation is known in the literature for a long time. Hantsch reported for the first time in 1900 a strategy for the synthesis of 1,2-iodoazides using silver azide and iodine in ether.⁹ 1,2-Iodoazides can also be synthesized by treating ICl/NaN_3 ,¹⁰ $\text{PhI}(\text{OAc})_2/\text{Et}_4\text{NX}/\text{TMSN}_3$,¹¹ $\text{CAN}/\text{NaI}/\text{NaN}_3$,¹² $\text{IPy}_2\text{BF}_4/\text{TMSN}_3$,¹³ and Oxone/wet $\text{Al}_2\text{O}_3/\text{KI}/\text{NaN}_3$ ¹⁴ with alkenes under various conditions. Poor selectivity and instability of these iodoazides are the main problems of these methods. Later, Hassner developed a procedure for *vic*-bromoazidation of alkene by addition of bromine azide generated from bromine and sodium azide.¹⁵ This procedure requires the use of excess hydrazoic acid to suppress the formation of dibromo compounds. A similar procedure was also reported by Krief for bromoazidation of alkenes by bromine azide

which was generated in situ from NBS and NaN_3 .¹⁶ Olah employed NBS and TMSN_3 for the bromoazidation of alkenes in the presence of Nafion-H in DME/ H_2O .¹⁷ However this procedure was reported only for 1,2-disubstituted and trisubstituted alkenes and there was no reaction with terminal alkenes. Recently, Hajra et al reported a method for 1,2-bromoazidation of alkenes using NBS and TMSN_3 in the presence of $\text{Zn}(\text{OTf})_2$ catalyst,^{18,19} however, metal triflates are highly expensive. Although, this method works well with terminal and 1,2-disubstituted olefins, α,β -unsaturated carbonyl compounds take much longer time and require higher temperature to achieve a good yield. Moreover, for chalcone, the reaction does not go into completion even after a long reaction time at a high temperature with a poor yield. Bromoazidation with α,β -unsaturated carboxylic acid derivatives also takes much longer time even at a higher temperature.¹⁹ Therefore, the development of efficient methods for *vicinal* bromoazidation of alkenes, particularly in the case of α,β -unsaturated alkenes, remains a challenging task. We are reporting herein a rapid and efficient procedure for the vicinal bromoazidation of alkenes using *N,N*-dibromo-*p*-toluenesulfonamide (TsNBr_2) as bromine source and TMSN_3 as azide source (Scheme 1). This reaction works well with all kinds of alkenes including α,β -unsaturated carbonyl compounds at room temperature within a very short time, without any catalyst.

N,N-Dibromo-*p*-toluenesulfonamide is known for a long time for aminobromination reaction in organic synthesis. Since the discovery of this reagent by Kharasc,²⁰ it has been utilized for

* Corresponding author. Tel.: +91 94351 11114.

E-mail address: pphukan@yahoo.com (P. Phukan).



Scheme 1.

Table 1
 Synthesis of bromoazides in different solvents

Entry	Solvent	Yield (%)
1	CH ₃ CN	76
2	CH ₂ Cl ₂	76
3	Toluene	58
4	CCl ₄	61
5	DMF	58
6	Acetone	39

Reaction conditions: olefin (1 mmol), TMSN₃ (1.1 mmol), TsNBr₂ (1.2 mmol), solvent (2 mL), rt, 10 min.

aminobromination of a variety of olefinic substrates.²¹ Recently, we have also developed a method for the synthesis of bromohydrins and alkoxy bromides using TsNBr₂.²² The brominating agent TsNBr₂ employed for this purpose was prepared from Chloramine-T by following literature procedure.²³

To begin with, a study on the bromoazidation reaction was carried out with ethyl cinnamate as a model substrate. The reaction

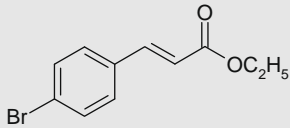
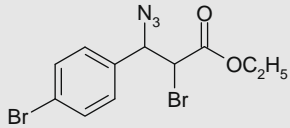
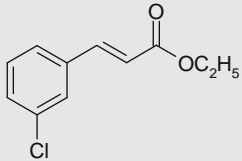
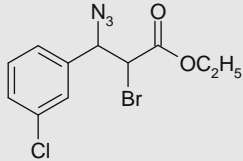
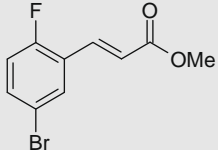
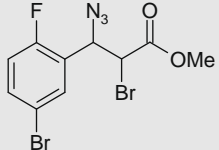
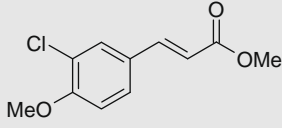
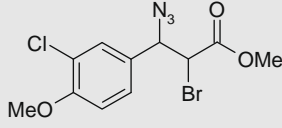
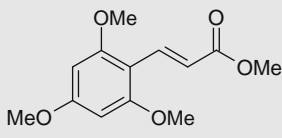
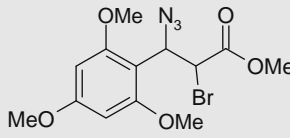
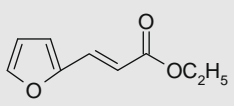
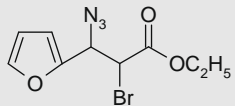
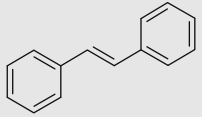
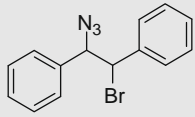
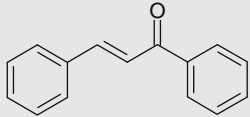
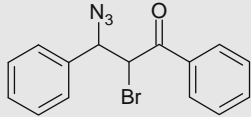
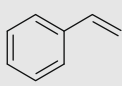
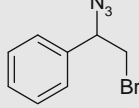
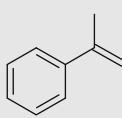
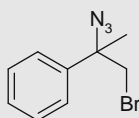
was carried out by adding TMSN₃ to the solution of ethylcinnamate in acetonitrile followed by the addition of TsNBr₂. The whole process was carried out at room temperature under nitrogen atmosphere. The reaction was studied by using 1.1 equiv of TMSN₃ (based on the olefinic substrate) and 1.2 equiv of TsNBr₂. We observed that after addition, the olefin disappears instantaneously, which was confirmed by monitoring the reaction by TLC. The reaction mixture was stirred for another 10 min. After usual work-up the corresponding bromoazide was obtained in an excellent yield. The reaction was further studied using different solvents such as dichloromethane, toluene, carbon tetrachloride, dimethylformamide, and acetone under the same reaction conditions (Table 1). Both acetonitrile and dichloromethane gave similar results for the azido-bromination reaction. However, use of other solvents such as toluene, carbon tetrachloride, DMF, and acetone was not fruitful (Table 1).

The reagent is much faster than NBS for bromoazidation reaction. Secondly, for NBS-assisted bromoazidation reaction, it is necessary to add a suitable catalyst to promote the reaction.^{17,18} But, in this case, reaction goes into completion without any catalyst. This process was extended to a variety of olefins in acetonitrile as solvent. The results are summarized in Table 2. Initially, we examined the reaction for different cinnamic esters. It can be seen from Table 2 that various cinnamic esters bearing functional groups such as –CH₃, –OMe, –Cl, and –F reacted successfully to give the corresponding 1,2-bromoazide in high yields irrespective of the substituent position on the aromatic ring.²⁴ Cinnamic esters having both electron-withdrawing and electron-donating groups could also be converted to the corresponding products in high yields. The reaction is regioselective, however, moderate stereoselectivity

Table 2
 Bromoazidation of various alkenes with TsNBr₂ and TMSN₃^a

Entry	Alkene (a)	Product (b)	Yield ^b	anti/syn ratio ^c
1			76	70:30
2			78	73:27
3			85	64:36
4			86	56:44
5			83	nd

Table 2 (continued)

Entry	Alkene (a)	Product (b)	Yield ^b	anti/syn ratio ^c
6			84	nd
7			85	nd
8			85	69:31
9			83	80:20
10			70	>99:1
11			52	nd
12			85	>99:1
13			69	>99:1
14			82	—
15			77	—

(continued on next page)

Table 2 (continued)

Entry	Alkene (a)	Product (b)	Yield ^b	anti/syn ratio ^c
16			78	—
17			49	—
18			48	—
19			50	—

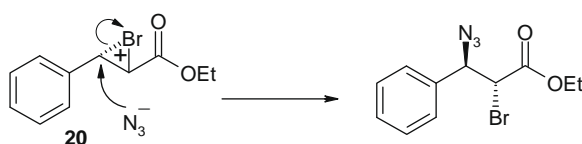
^a Reaction condition: olefin (1 mmol), TMSN₃ (1.1 mmol), TsNBr₂ (1.2 mmol), MeCN (2 mL), rt, 10 min.

^b Isolated yield after chromatographic purification.

^c anti/syn ratio was determined from NMR spectral data; nd: not determined.

was obtained for most of the cases. Bromoazides produced from cinnamic esters have anti/syn ratio of about 3:1 which was determined from the ¹H NMR analysis. Interestingly, the reaction is highly stereoselective in case of 2',4',6'-trimethoxycinnamate yielding only the erythro-β-azido-α-bromo isomer as evident by the analysis of ¹H NMR data. The same result of exclusive anti-selectivity was also observed in the case of stilbene and chalcone (Table 1, entry 9). After being successful in the case of cinnamic esters, stilbene, and chalcone, we extended the procedure to styrenes and ethyl acrylate, which produced the corresponding bromoazide in high yields. The procedure was further examined in the case of 3-(2-furyl) acrylate, cyclohexene, allyloxybenzene, and 1-octene. But the reaction was not successful with these substrates. Lower yield of the corresponding product was observed in all the cases.

A probable mechanistic pathway to explain the regio- and stereoselectivity of the bromohydrins and bromoethers is depicted in Scheme 2. A three-membered cyclic bromonium ion intermediate **20** is formed at the initial stage of the reaction due to electrophilic addition of the Br⁺ ion (generated from TsNBr₂) onto the olefin.²⁵ The regioselectivity can be explained by considering the fact that the β-position is more positive than the α-position due to the presence of the aromatic ring. Nucleophilic opening of the cyclic bromonium intermediate is most likely from the more positive β-position. The opening of the intermediate **20** by the azide ion via the S_N² pathway is most probable, which is responsible for the anti-stereoselectivity. However, the reason for the moderate anti-selectivity may be the bromonium ion **20** which may be partially open in the vicinity of the aromatic ring. Moreover, the N₃⁻ ion is a stronger nucleophile, being less selective, resulting in instantaneous formation of a mixture of isomers.



Scheme 2. Probable mechanistic pathway.

In conclusion, an efficient protocol for vicinal bromoazidation of olefins has been established by using *N,N*-dibromo-*p*-toluenesulfonamide in acetonitrile at room temperature without the use of any catalyst. The procedure is extremely fast, easy to perform at room temperature, and applicable to various olefins such as cinnamates, chalcone, styrenes, and acrylate to give corresponding 1,2-bromoazide in high yields. However, the reaction is not very effective in the case of aliphatic alkenes such as cyclohexene and 1-octene. The study in this area is in progress.

Acknowledgment

Financial support from DST (Grant No. SR/S1/RFPC-07/2006) is gratefully acknowledged.

References and notes

- (a) Sheradsky, T. In *The Chemistry of the Azido Group*; Patai, S., Ed.; Interscience: New York, 1971; p 331; (b) Scriven, E. F. V.; Turnbull, K. *Chem. Rev.* **1988**, *88*, 297–368; (c) Bräse, S.; Gil, C.; Knepper, K.; Zimmermann, V. *Angew. Chem., Int. Ed.* **2005**, *44*, 188–5240.
- (a) Boyer, J. H. *J. Am. Chem. Soc.* **1951**, *73*, 5865; (b) Wasserman, H. H.; Brunner, R. K.; Buynak, J. D.; Carter, C. G.; Oku, T.; Robinson, R. P. *J. Am. Chem. Soc.* **1985**, *107*, 519–521.
- (a) Huisgen, R. *Angew. Chem., Int. Ed.* **1963**, *2*, 565–598; (d) Tornøe, C. W.; Christensen, C.; Meldal, M. *J. Org. Chem.* **2002**, *67*, 3057–3064; (e) Rostovtsev, V. V.; Green, L. G.; Fokin, V. V.; Sharpless, K. B. *Angew. Chem., Int. Ed.* **2002**, *41*, 2596–2599; (f) Amantini, D.; Fringuelli, F.; Piermatti, O.; Pizzo, F.; Zunino, E.; Vaccaro, L. *J. Org. Chem.* **2005**, *70*, 6526.
- (a) Kolb, H. C.; Finn, M. G.; Sharpless, K. B. *Angew. Chem., Int. Ed.* **2001**, *40*, 2004–2021; (b) Kolb, H. C.; Sharpless, K. B. *Drug Discovery Today* **2003**, *8*, 1128–1137; (c) Breinbauer, R.; Köhn, M. *ChemBioChem.* **2003**, *4*, 1147–1149; (d) Bock, V. D.; Hiemstra, H.; van Maarseveen, J. H. *Eur. J. Org. Chem.* **2006**, 51–68.
- Hassner, A.; Fowler, F. W. *J. Org. Chem.* **1968**, *33*, 2686–2691.
- Wasserman, H. H.; Brunner, R. K.; Buynak, J. D.; Carter, C. G.; Oku, T.; Robinson, R. P. *J. Am. Chem. Soc.* **1985**, *107*, 519–521.
- (a) Van Ende, D.; Krief, A. *Angew. Chem.* **1974**, 279–280; (b) Denis, J. N.; Krief, A. *Tetrahedron* **1979**, *35*, 2901–2903.
- (a) Ranganathan, S.; Ranganathan, D.; Mehrotra, A. K. *Tetrahedron Lett.* **1973**, *14*, 2265–2268; (b) Moorthy, S. N.; Devaprabhakar, D. *Tetrahedron Lett.* **1975**, *16*, 257–260.
- Hantzsch, A.; Schumann, M. *Ber. Dtsch. Chem. Ges.* **1900**, *33*, 522.
- (a) Hassner, A.; Levy, L. A. *J. Am. Chem. Soc.* **1965**, *87*, 4203–4204; (b) Fowler, F. W.; Hassner, A.; Levy, L. A. *J. Am. Chem. Soc.* **1967**, *89*, 2077–2082.
- Kirschning, A.; Hashem, M. A.; Monenschein, H.; Rose, L.; Schoning, K.-U. *J. Org. Chem.* **1999**, 6522–6526.

12. Nair, V.; George, T. G.; Sheeba, V.; Augustine, A.; Balagopal, L.; Nair, L. G. *Synlett* **2000**, 1597–1598.
13. Barluenga, J.; Alvarez-Perez, M.; Fananas, F. J.; Gonzales, J. M. *Adv. Synth. Catal.* **2001**, 335–337.
14. Curini, M.; Epifano, F.; Marcotullio, M. C.; Rosati, O. *Tetrahedron Lett.* **2002**, *43*, 1201–1203.
15. (a) Hassner, A.; Boerwinkle, F. *J. Am. Chem. Soc.* **1968**, *90*, 216–218; (b) Boerwinkle, F.; Hassner, A. *Tetrahedron Lett.* **1968**, *9*, 3921–3924; (c) Hassner, A.; Boerwinkle, F. *Tetrahedron Lett.* **1969**, *10*, 3309–3312.
16. (a) Van Ende, D.; Krief, A. *Angew. Chem., Int. Ed. Engl.* **1974**, *13*, 279–280; (b) Denis, J. N.; Krief, A. *Tetrahedron* **1979**, *35*, 2901–2903.
17. Olah, G. O.; Wang, Q.; Li, X.-Y.; Prakash, G. K. S. *Synlett* **1990**, 487–489.
18. Hajra, S.; Sinha, D.; Bhowmick, M. *Tetrahedron Lett.* **2006**, *47*, 7017–7019.
19. Hajra, S.; Bhowmick, M.; Sinha, D. *J. Org. Chem.* **2006**, 9237–9240.
20. Kharasch, M. S.; Priestley, H. N. *J. Am. Chem. Soc.* **1939**, *61*, 3425.
21. (a) Terauchi, H.; Kowata, K.; Minematsu, T.; Takemura, S. *Chem. Pharm. Bull.* **1977**, *25*, 556; (b) Hegedus, L. S.; McKearin, J. M. *J. Am. Chem. Soc.* **1982**, *104*, 2444; (c) Revesz, L.; Blum, E.; Wicki, R. *Tetrahedron Lett.* **2005**, *46*, 5577; (d) Griffith, D. A.; Danishefsky, S. J. *J. Am. Chem. Soc.* **1996**, *118*, 9526; (e) Shen, R.; Huang, X. *J. Org. Chem.* **2007**, *72*, 3961; (f) Han, J.; Li, T.; Pan, Y.; Kattuboina, A.; Li, G. *Chem. Biol. Drug. Des.* **2008**, *71*, 71–77.
22. Phukan, P.; Chakraborty, P.; Kataki, D. *J. Org. Chem.* **2006**, *71*, 7533–7537.
23. Nair, C. G. R.; Indrasen, P. *Talanta* **1976**, *23*, 239.
24. *General procedure for synthesis of bromoazides:* To a solution of olefin (1 mmol) in acetonitrile (2 ml) TMSN₃ (1.1 mmol), and then TsNBr₂ (1.2 mmol) were added under nitrogen atmosphere and stirred. After completion of the reaction sodium thiosulfate (200 mg approx.) was added and the reaction mixture was stirred for 15 minutes. The reaction mixture was taken up in ethyl acetate, dried over anhydrous sodium sulfate, and concentrated. The crude product was purified by flash chromatography on silica gel (230–400 mesh) with petroleum ether/ethyl acetate (98:2) as eluent. *Representative spectral data:* (**±**)**1b**: IR (KBr, cm⁻¹) ν : 2106.4, 1743, 1265.6, 1022, 740.4; ¹H NMR (CDCl₃, 400 MHz) δ : 7.46–7.32 (m, 5H), 5.21 (d, *J* = 6.5 Hz, 1H), 4.39 (d, *J* = 9.5 Hz, 1H), 4.34–4.29 (m, 2H), 1.34 (t, *J* = 3.6, 3H); ¹³C NMR (CDCl₃, 100 MHz) δ : 14.1, 49.5, 52.6, 62.5, 67.2, 128.3, 128.3, 128.8, 129.0, 129.5. GC–MS (*M/Z*%): 269 (*M*⁺–28, N₂ elimination, 62), 271 (62), 195 (62), 197 (59), 189 (33), 162 (26), 143 (59), 116 (87), 90 (100), 63 (44), 29 (77); (**±**)**7b**: IR (KBr, cm⁻¹) ν : 2116, 1721, 1263, 1084, 742; ¹H NMR (CDCl₃, 400 MHz) δ : 7.39–7.23 (m, 4H), 5.12 (d, *J* = 9.2 Hz, 1H), 4.367 (d, *J* = 9.2 Hz, 1H), 3.83 (s, 3H); ¹³C NMR (CDCl₃, 100 MHz) δ : 168.0, 138.8, 130.3, 129.8, 128.7, 126.7, 67.3, 53.4, 53.3, 48.2; GC–MS (*M/Z*%): 289 (*M*⁺–28, N₂ elimination, 37), 291 (44), 231 (67), 229 (56), 204 (11), 182 (10), 153 (100), 139 (16), 123 (51), 116 (34), 89 (95), 76 (33), 63 (35.14), 39 (16.71), 28 (16.31), 18 (9.02), 15 (8.36); (**±**)**12b**: IR (KBr, cm⁻¹) ν : 2986, 2366, 2110 (N₃), 1740, 1276, 656. ¹H NMR (CDCl₃, 400 MHz) δ : 1.331 (t, *J* = 7.2 Hz, 3H), 3.93–3.88 (q, *J* = 8.4 Hz, 2H), 4.28 (t, *J* = 7.6 Hz, 1H). ¹³C NMR (CDCl₃, 100 MHz) δ : 13.9, 29.7, 41.3, 53.3, 62.7.
25. Rodebaugh, R.; Fraser-Reid, B. *Tetrahedron* **1996**, *52*, 7663–7678.