Available online at www.sciencedirect.com

SCIENCE DIRECT®

Tetrahedron Letters 46 (2005) 657–659

Tetrahedron Letters

Three-component reactions of polynitromethanes with alkynes. The first synthesis of *gem*-dinitroaziridines

Ekaterina M. Budynina, Elena B. Averina, Olga A. Ivanova, Tamara S. Kuznetsova* and Nikolai S. Zefirov

Department of Chemistry, Moscow State University, Leninskie Gory, 119992 Moscow, Russia

Received 14 October 2004; revised 17 November 2004; accepted 25 November 2004
Available online 10 December 2004

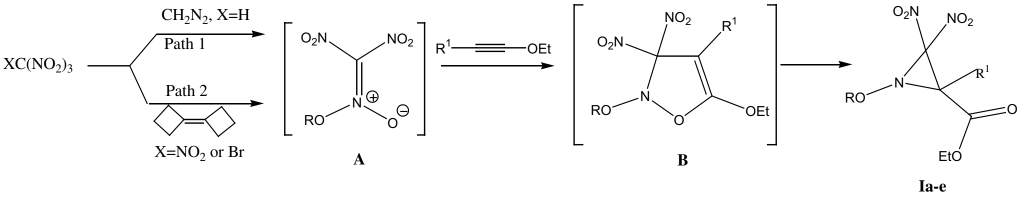
Abstract—Three-component one-pot reactions of tetranitro- and bromotrinitromethanes with alkoxyacetylenes, mediated by diazomethane or bicyclobutylidene, yielding *gem*-dinitroaziridines via sequential electrophile transfer followed by [3+2]-cycloaddition, have been studied. A series of novel *N*-alkoxy-2,2-dinitroaziridines have been prepared by these reactions.

Reactions of polynitromethanes with alkenes have been known for many years.[1] It is commonly accepted that, at first, the unstable dinitronitronate is formed as an intermediate, which then quickly undergoes [3+2]-cycloaddition with an alkene to yield 3,3-dinitroisoxazolidines.

Recently we have developed the stepwise, three-component, one-pot version of the reactions of polynitromethanes with alkenes.[2] The first step is an in situ formation of dinitronitronate as a result of the interaction between one molecule of polynitromethane and one molecule of the alkene. Then another alkene takes part in the [3+2]-cycloaddition step with the dinitronitronate so generated. This procedure has allowed us to synthesize a number of isoxazolidines.

The involvement of alkynes into reactions with polynitroalkanes is still unknown and the purpose of the present paper is to fill this gap. As we have shown in preliminary studies commonly used alkynes such as 1-hexyne or phenylacetylene do not react directly with polynitromethanes. Thus their potential involvement into such processes can only be related to the [3+2]-cycloaddition with dinitronitronates, that is, as the second stage of the three-component tandem reaction.

We have used two alternative ways to generate dinitronitronate **A** (Scheme 1). The first one is alkylation of a nitro group in trinitromethane by diazomethane[3] (path 1, Scheme 1). The second is a reaction between tetranitromethane or bromotrinitromethane and an alkene[4] (Scheme 1, path 2). According to our previous results,[2]



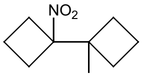
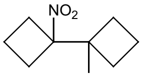
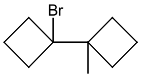
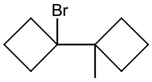
Scheme 1.

Keywords: Tetranitromethane; Trinitromethane; Bromotrinitromethane; Alkoxyacetylenes; Nitronate; [3+2]-Cycloaddition; *gem*-Dinitroaziridines.

* Corresponding author. Tel.: +7 095 9393969; fax: +7 095 9390290; e-mail: kuzn@org.chem.msu.ru

doi:10.1016/j.tetlet.2004.11.126

Table 1.

X	Aziridine	R	R^1	dr	Yield (%)
H	**1a**	Me	H	—[a]	78
NO_2	**1b**		H	6:1	86
NO_2	**1c**		Et	3:1	18
Br	**1d**		H	7:3	25
Br	**1e**		Et	3:1	18

[a] The signals of the second diastereomer were not observed in the NMR spectra.

bicyclobutylidene is an ideal precursor to generate dinitronitronate in situ because of its high reactivity towards polynitromethanes and low reactivity as a dipolarophile in [3+2]-cycloaddition reactions with the dinitronitronate so generated.

We found that electron rich alkynes, such as ethoxyacetylene and 1-ethoxy-1-butyne, reacted as dipolarophiles with dinitronitronates **A** to provide unstable 3,3-dinitro-2,3-dihydroisoxazoles **B** (Scheme 1), which then underwent a spontaneous rearrangement[5] (in principle a 1,3-sigmatropic rearrangement) to afford *gem*-dinitroaziridines **1a**–**e**[6] (Scheme 1, Table 1). To the best of our knowledge these compounds have not been previously reported.

The three-component reaction of tetranitromethane or bromotrinitromethane with bicyclobutylidene and the terminal alkyne ethoxyacetylene occurred with high regioselectivity and resulted exclusively in *gem*-dinitroaziridines **1b** and **1d**, respectively (Table 1). The reactivity of disubstituted alkynes such as 1-ethoxy-1-butyne as the dipolarophile in the [3+2]-cycloaddition reactions with dinitronitronates **A** was much lower than that of ethoxyacetylene, and comparable to that of the starting alkene, bicyclobutylidene. As a result, aziridines **1c** and **1e** were formed along with isoxazolidines from bicyclobutylidene[2b,7] as side products.

This novel synthetic protocol to obtain *gem*-dinitroaziridines is a one-pot process, which includes stirring equimolar amounts of tetranitromethane or bromotrinitromethane, bicyclobutylidene and the starting acetylene in hexane at room temperature. Another preparative version is stirring equimolar amounts of trinitromethane, diazomethane and the starting acetylene.

The structures of **1a**–**e** were proved unambiguously by NMR spectra and elemental analysis.[6] According to the NMR data, aziridines **1b**–**e** were obtained as a mixture of two diastereomers (Table 1). It is known[8] that aziridines bearing electron-withdrawing substituents on nitrogen atom possess high inversion barriers and can exist as a mixture of two invertomers at room temperature.

The route described above to dinitroaziridines is limited by the use of electron rich acetylenes. Acetylenes containing alkyl or electron-withdrawing substituents such as 1-hexyne, 1-heptyne, phenylacetylene, dicarbomethoxyacetylene do not reacted with nitronates **A**.

A detailed mechanistic study of these three-component reactions and the properties of the *gem*-dinitroaziridines are currently in progress.

Caution: *Although we have not met any problems in handling these compounds, full safely precautions should be taken due to their potentially explosive nature.*

References and notes

1. (a) Altukhov, K. V.; Perekalin, V. V. *Usp. Khim. (Russ.)* **1976**, *45*, 2050–2076; *Chem. Abstr.* **1977**, *86*, 71774s; (b) Fridman, A. L.; Surkov, V. D.; Novikov, S. S. *Usp. Khim. (Russ.)* **1980**, *49*, 2159–2187; *Chem. Abstr.* **1981**, *94*, 156194f; (c) Schvekhgeimer, G. A.; Zvolinskii, V. I.; Kobrakov, K. I. *Khim. Geterotsikl. Soedin. (Russ.)* **1986**, *4*, 435–452; *Khim. Chem. Abstr.* **1987**, *106*, 50078j.
2. (a) Budynina, E. M.; Ivanova, O. A.; Averina, E. B.; Grishin, Yu. K.; Kuznetsova, T. S.; Zefirov, N. S. *Dokl. Akad. Nauk. (Russ.)* **2002**, *382*, 210–213; *Dokl. Chem. (Engl. Transl.)* **2002**, *382*, 16–18; (b) Budynina, E. M.; Ivanova, O. A.; Averina, E. B.; Grishin, Yu. K.; Kuznetsova, T. S.; Zefirov, N. S. *Dokl. Akad. Nauk. Russ.* **2002**, *387*, 200–203; *Dokl. Chem. (Engl. Transl.)* **2002**, *387*, 304–307; (c) Budynina, E. M.; Ivanova, O. A.; Averina, E. B.; Kuznetsova, T. S.; Zefirov, N. S. *Zh. Org. Khim. (Russ)*. **2003**, *39*(5), 783–785; *Russ. J. Org. Chem. (Engl. Transl.)* **2003**, *39*, 736–738; (d) Averina, E. B.; Budynina, E. M.; Ivanova, O. A.; Grishin, Yu. K.; Gerdov, S. M.; Kuznetsova, T. S.; Zefirov, N. S. *Zh. Org. Khim. (Russ)*. **2004**, *40*, 186–198; *Russ. J. Org. Chem. (Engl. Transl.)* **2004**, *40*, 162–173.
3. (a) Arndt, F.; Rose, J. D. *J. Chem. Soc.* **1935**, 1–10; (b) Tartakovskii, V. A.; Chlenov, I. E.; Ioffe, S. L.; Lagodzinskaya, G. V.; Novikov, S. S. *Zh. Org. Khim. (Russ.)* **1966**, *2*, 1593–1599; *J. Org. Chem. USSR (Engl. Transl.)* **1966**, *2*, 1573–1579.
4. (a) Altukhov, K. V.; Perekalin, V. V. *Zh. Org. Khim. (Russ.)* **1967**, *3*, 2003–2008; *J. Org. Chem. USSR (Engl. Transl.)* **1967**, *3*, 1953–1958; (b) Altukhov, K. V.; Ratsino, E. V.; Perekalin, V. V. *Zh. Org. Khim. Russ.* **1973**, *9*, 269–273; *J. Org. Chem. USSR (Engl. Transl.)* **1973**, *9*, 267.
5. (a) Seebach, D.; Lyapkalo, I. M.; Dahinden, R. *Helv. Chim. Acta* **1999**, *82*, 1829–1842; (b) Tartakovskii, V. A.; Luk'yanov, O. A.; Novikov, S. S. *Izv. Akad. Nauk. Ser. Khim. (Russ.)* **1966**, 2246–2247; *Bull. Acad. Sci. USSR Div. Chem. Sci. (Engl. Transl.)* **1966**, 2186–2187; (c) Tartakovskii, V. A.; Luk'yanov, O. A.; Novikov, S. S. *Dokl. Akad. Nauk. (Russ.)* **1968**, *178*, 123–126; *Dokl. Chem. (Engl. Transl.)* **1968**, *178*, 21–24; (d) Chlenov, I. E.; Sokolova, I. L.; Novikov, S. S.; Tartakovskii, V. A. *Izv. Akad. Nauk. Ser. Khim. (Russ.)* **1973**, 473–474; *Bull. Acad. Sci. USSR Div. Chem. Sci. (Engl. Transl.)* **1973**, 460–461; (e) Gree, R.; Carrie, R. *J. Chem. Soc., Chem. Commun.* **1975**, 112–113; (f) Gree, R.; Carrie, R. *J. Am. Chem. Soc.* **1977**, *99*(20), 6667–6672.

6. *Ethyl 1-methoxy-3,3-dinitroaziridine-2-carboxylate* (**1a**). To a solution of trinitromethane (0.755 g, 5 mmol) in 10 mL benzene a solution of diazomethane (from 2 g, 19 mmol, *N*-nitroso-*N*-methylurea) in 25 mL benzene was added dropwise under stirring at 5 °C. To the resulting solution, ethoxyacetylene (0.35 g, 5 mmol) was add in one portion. The mixture was stirred for 0.5 h. The solvent was removed by evaporation under vacuum. The residue was dissolved in 1 mL $CHCl_3$. The product was isolated by column chromatography ($CHCl_3$–hexane, 1:2). Yield 0.91 g (78%), R_f ($CHCl_3$) 0.47. ^1H NMR (300 MHz, $CDCl_3$) δ 1.30 (t, $^3J = 7.1$, 3H, CH_3), 3.87 (s, 3H, OCH_3), 4.25–4.32 (m, 2H, OCH_2), 4.42 (s, 1H, CH). ^{13}C NMR (75 MHz, $CDCl_3$) δ 13.73 (CH_3), 53.33 (CH), 63.49 (OCH_3), 63.99 (OCH_2), 101.35 ($C(NO_2)_2$), 160.27 (COOEt). Anal. Calcd for $C_6H_9N_3O_7$: C, 30.65; H, 3.86%. Found: C, 30.58; H, 3.71%.

   Aziridines **1b–e**. *Typical procedure*. The corresponding alkyne (2.5 mmol) was added to a cooled (0 °C) solution of $XC(NO_2)_3$ ($X = NO_2$, Br) (2.5 mmol) and bicyclobutylidene (2.5 mmol) in 5 mL hexane. The reaction mixture was warmed up to room temperature and stirred for 24 h. The solvent was evaporated and the residue was dissolved in 1 mL $CHCl_3$. The products were isolated by column chromatography ($CHCl_3$–hexane, 1:2).

   Ethyl 3,3-dinitro-1-{1′-nitro-1,1′-bi(cyclobutyl)-1-yl-oxy}-aziridine-2-carboxylate (**1b**) (dr **A**/**B** = 6:1). After column chromatography 0.11 g (12%) **B**, R_f ($CHCl_3$) 0.57 and 0.69 g (74%) **A**, R_f ($CHCl_3$) 0.41, were obtained. ^1H NMR (300 MHz, $CDCl_3$) δ **A**: 1.30 (t, $^3J = 7.2$, 3H, CH_3), 1.76–1.92 (m, 3H, cy-Bu), 1.94–2.08 (m, 2H, cy-Bu), 2.42–2.73 (m, 4H, cy-Bu), 2.45–2.92 (m, 3H, cy-Bu), 4.28 (q, $^3J = 7.2$, 2H, CH_2O), 4.38 (s, 1H, CH); **B**: 1.31 (t, $^3J = 7.2$, 3H, CH_3), 1.76–1.92 (m, 3H, cy-Bu), 1.94–2.08 (m, 2H, cy-Bu), 2.42–2.73 (m, 4H, cy-Bu), 2.45–2.92 (m, 3H, cy-Bu), 4.29 (q, $^3J = 7.2$, 2H, CH_2O), 5.81 (s, 1H, CH). ^{13}C NMR (75 MHz, $CDCl_3$) δ **A**: 13.93 (CH_3), 14.07 (CH_2, cy-Bu), 14.57 (CH_2, cy-Bu), 27.02 (CH_2, cy-Bu), 27.56 (CH_2, cy-Bu), 28.98 (CH_2, cy-Bu), 30.76 (CH_2, cy-Bu), 52.64 (CH, *J* 181), 63.90 (CH_2O), 90.75 (C, cy-Bu), 92.11 (C, cy-Bu), 100.41 ($C(NO_2)_2$), 160.32 (COOEt). Anal. Calcd for $C_{13}H_{18}N_4O_9$: C, 41.71; H, 4.85%. Found: C, 41.70; H 4.70%.

   Ethyl 3,3-dinitro-1-{[1′-nitro-1,1′-bi(cyclobutyl)-1-yl]-oxy}-2-ethylaziridine-2-carboxylate (**1c**) (dr **A**/**B** = 3:1). Yield 0.18 g (18%), R_f ($CHCl_3$) 0.58, 0.48 (**A**+**B**). ^1H NMR (300 MHz, $CDCl_3$) δ **A**: 1.12 (t, $^3J = 7.6$, 3H, CH_3), 1.29 (t, $^3J = 7.1$, 3H, CH_3), 1.60–3.00 (m, 14H, cy-Bu, $C\mathit{H}_2$–CH_3), 4.25 (q, $^3J = 7.1$, 2H, OCH_2); **B**: 1.04 (t, $^3J = 7.0$, 3H, CH_3), 1.21 (t, $^3J = 6.9$, 3H, CH_3), 1.60–3.00 (m, 14H, cy-Bu, CH_2), 4.31 (q, $^3J = 6.9$, 2H, OCH_2). ^{13}C NMR (75 MHz, $CDCl_3$) δ **A**: 9.49 (CH_3), 13.60 (CH_2, cy-Bu), 13.74 (CH_3), 14.49 (CH_2, cy-Bu), 27.34 (CH_2), 27.78 (CH_2), 28.88 (CH_2), 29.12 (CH_2), 29.79 (CH_2), 62.92 (CN), 63.41 (OCH_2), 89.92 (C, cy-Bu), 91.46 (C, cy-Bu), 98.52 ($C(NO_2)_2$), 162.09 (COOEt). Anal. Calcd for $C_{15}H_{22}N_4O_9$: C, 44.78; H, 5.51%. Found: C, 45.12; H, 5.79%.

   Ethyl 1-{[1′-bromo-1,1′-bi(cyclobutyl)-1-yl]-oxy}-3,3-dinitroaziridine-2-carboxylate (**1d**) (dr **A**/**B** = 7:3). Yield 0.26 g (25%), R_f ($CHCl_3$) 0.78, 0.68 (**A**+**B**). ^1H NMR (300 MHz, $CDCl_3$) δ **A**: 1.27 (t, $^3J = 7.1$, 3H, CH_3), 1.59–2.22 (m, 6H, cy-Bu), 2.15–2.43 (m, 4H, cy-Bu), 2.54–2.75 (m, 2H, cy-Bu), 4.26 (q, $^3J = 7.1$, 2H, CH_2O), 4.53 (s, 1H, CH); **B**: 1.33 (t, $^3J = 7.0$, 3H, CH_3), 1.59–2.22 (m, 6H, cy-Bu), 2.15–2.43 (m, 4H, cy-Bu), 2.54–2.75 (m, 2H, cy-Bu), 4.31 (q, $^3J = 7.0$, 2H, CH_2O), 5.80 (s, 1H, CH). ^{13}C NMR (75 MHz, $CDCl_3$) δ **A**: 12.08 (CH_3), 13.85 (CH_2, cy-Bu), 16.76 (CH_2, cy-Bu), 27.77 (CH_2, cy-Bu), 28.39 (CH_2, cy-Bu), 35.67 (CH_2, cy-Bu), 35.76 (CH_2, cy-Bu), 52.48 (CH, $J = 180$), 63.75 (CH_2O), 71.56 (CBr), 91.17 (C, cy-Bu), 100.38 ($C(NO_2)_2$), 160.37 (COOEt); **B**: 12.57 (CH_3), 14.30 (CH_2, cy-Bu), 16.21 (CH_2, cy-Bu), 28.50 (CH_2, cy-Bu), 29.66 (CH_2, cy-Bu), 35.29 (CH_2, cy-Bu), 36.28 (CH_2, cy-Bu), 52.54 (CH), 63.80 (CH_2O), 68.54 (CBr), 93.94 (C, cy-Bu), 103.94 ($C(NO_2)_2$), 164.73 (COOEt). Anal. Calcd for $C_{13}H_{18}BrN_3O_7$: C, 38.25; H, 4.44%. Found: C, 38.16; H, 4.29%.

   Ethyl 1-{[1′-bromo-1,1′-bi(cyclobutyl)-1-yl]-oxy}-3,3-dinitro-2-ethylaziridine-2-carboxylate (**1e**) (dr **A**/**B** = 3:1). Yield 0.20 g (18%). After column chromatography the only diastereomer was obtained, R_f ($CHCl_3$) 0.86. ^1H NMR (300 MHz, $CDCl_3$) δ **A**: 1.18 (t, $^3J = 7.6$, 3H, CH_3), 1.36 (t, $^3J = 7.1$, 3H, CH_3), 1.57–2.90 (m, 14H, cy-Bu, $C\mathit{H}_2$–CH_3), 4.33 (q, $^3J = 7.1$, 2H, OCH_2). ^{13}C NMR (75 MHz, $CDCl_3$) δ **A**: 6.86 (CH_3), 13.69 (CH_2, cy-Bu), 13.91 (CH_3), 15.24 (CH_2, cy-Bu), 28.86 (CH_2), 29.67 ($2 \times CH_2$), 32.77 (CH_2), 36.83 (CH_2), 62.32 (CH_2O), 63.71 (C), 68.68 (CBr), 90.62 (C, cy-Bu), 98.26 ($C(NO_2)_2$), 161.10 (COOEt). Anal. Calcd for $C_{15}H_{22}BrN_3O_7$: C, 41.30, H, 5.08%. Found: C, 41.34; H, 5.30%.

7. (a) Averina, E. B.; Ivanova, O. A.; Grishin, Yu. K.; Kuznetsova, T. S.; Zefirov, N. S. *Zh. Org. Khim. (Russ.)* **2000**, *36*, 1609–1614; *Russ. J. Org. Chem. (Engl. Transl.)* **2000**, *36*, 1562–1567.

8. (a) Brois, S. J. *J. Am. Chem. Soc.* **1968**, *90*, 506–508, 508–509; (b) Sweeney, J. B. *Chem. Soc. Rev.* **2002**, *31*, 247–258.