Synthesis of 1-[(nitroxyalkoxy)methoxy]-1-triazene 2-oxides, new hybrid nitrogen monoxide donors*

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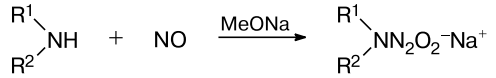
1-[(Nitroxyalkoxy)methoxy]-3,3-dialkyl-1-triazene 2-oxides were obtained by the reaction of 3,3-dialkyl-1-hydroxy-1-triazene 2-oxide sodium salts with β- or γ-nitroxyalcohol chloromethyl ethers or by the reaction of 3,3-dialkyl-1-(bromoalkoxymethoxy)-1-triazene 2-oxides with silver nitrate. These compounds can be of interest as new hybrid NO donors in living organisms.

Key words: chloromethyl ethers, nitroxy alcohols, nitrogen monoxide, 1-triazene 2-oxides, 1-chloromethoxy-3-nitroxypropane, silver nitrate, alkylation, bromination.

Nitrogen monoxide NO is one of the versatile and necessary regulators of cell metabolism functions in living organisms. At present, a wide enough body of chemical compounds capable of function as NO generators in mammal organisms is known: guanidine and hydroxylamine derivatives, *N*-nitro derivatives, C-nitrates and nitrites, as well as representatives of other classes of compounds[1] used in pharmacology. First of all, these are pharmaceutical agents from the family of organic nitrates: nitroglycerol, nitrosorbide, isosorbide mononitrate, erinite, nicorandil, *etc*. At the same time, active studies are conducted on the search for new compounds capable of generation of NO in living organisms. From this point of view, properties of 1-alkoxy-1-triazene 2-oxide derivatives, which were discovered relatively recently, are of undoubted interest.[2] In the last decade, a fast growth of publications devoted to these compounds is observed, in particular, to the in-depth biological studies or before-clinical testing of their pharmaceutical effects in the treatment of cardio-vascular system and kidney diseases, lung insufficiency, oncological diseases, diabetes.[3—5]

The purpose of our studies consists in the development of methods for the synthesis of potential hybrid-type NO donors containing both a nitrate group and an alkoxytriazene oxide fragment. No such compounds are known. Their molecules contain structural fragments of two known classes of compounds, whose many representatives are nitric oxide donors in living organisms, that suggests that similar useful properties would be possessed by the compounds to be synthesized. It should be noted that organic nitrates and functional oxytriazene oxides significantly differ in the rate of the NO generation, that gives us a possibility to design compounds with the favorable dynamics of the formation of nitric oxide, which can be regulated within a certain range. In this connection, we performed alkylation of a number of sodium salts of 3,3-disubstituted 1-hydroxy-1-triazene 2-oxides (**1**—**4**). These salts were obtained by the reaction of the corresponding amines with NO in the presence of sodium methoxide (Scheme 1).

Scheme 1

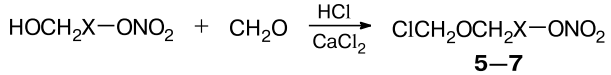


1—4

1: $R^1 = R^2 = Me$; **2:** $R^1 = Me$, $R^2 = Et$; **3:** $R^1 = R^2 = Et$; **4:** $R^1 + R^2 = (CH_2)_4$

Chloromethyl ethers **5**—**7** used as alkylating agents were obtained by the reaction of the corresponding alcohols with aqueous formaldehyde in the presence of hydrochloric acid and calcium chloride (Scheme 2).

Scheme 2



5—7

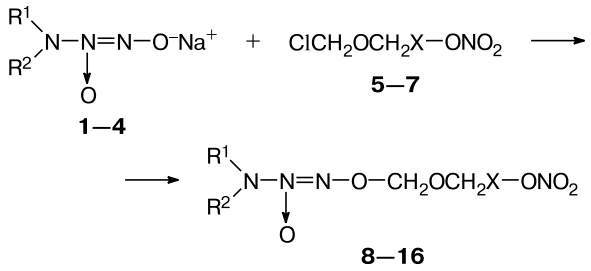
X = CH_2 (**5**), $(CH_2)_2$ (**6**), CH(Me) (**7**)

The reactions between salts **1**—**4** and chlorides **5**—**7** gave earlier unknown adducts **8**—**16** in 23—53% yields (Scheme 3).

* On the occasion of the 80th anniversary of the N. D. Zelinsky Institute of Organic Chemistry of the Russian Academy of Sciences.

Published in Russian in *Izvestiya Akademii Nauk. Seriya Khimicheskaya,* No. 2, pp. 0487—0490, February, 2014.

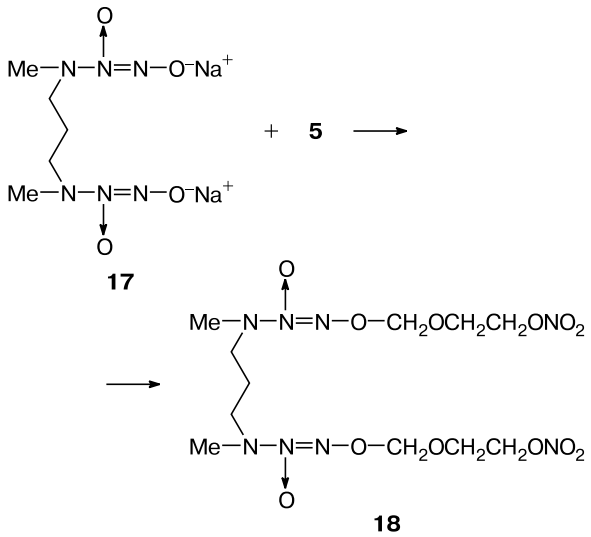
Scheme 3



Compound	R^1	$R^1 + R^2$	R^2	X
8	Me	—	Me	CH_2
9	Me	—	Et	CH_2
10	Et	—	Et	CH_2
11	—	$(CH_2)_4$	—	CH_2
12	Me	—	Me	$(CH_2)_2$
13	Me	—	Et	$(CH_2)_2$
14	—	$(CH_2)_4$	—	$(CH_2)_2$
15	Me	—	Me	CH(Me)
16	—	$(CH_2)_4$	—	CH(Me)

Dinitrate **18** was obtained in 18% yield by alkylation of bis-triazene disodium salt **17** with chloromethyl ether **5** in dimethylformamide (Scheme 4).

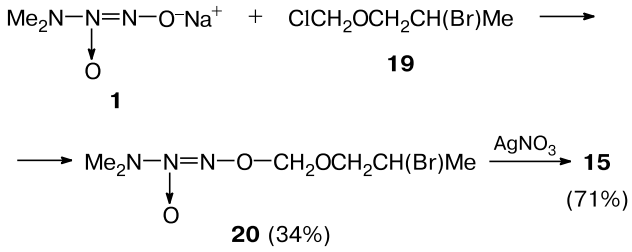
Scheme 4



It should be noted that anions of salts **1**—**4** and **17** to be alkylated are ambident, and the reaction can proceed either at the distal or the proximal oxygen atoms with the formation of triazene *N*-oxides or *N*-nitroso derivatives, respectively. However in all the cases, only triazene *N*-oxides were isolated. It is probable, that *N*-nitroso derivatives are also formed under these conditions, but, being unstable compounds, they would decompose in the course of the reactions or during isolation. This suggestion is also supported by the low yields of the alkylation products.

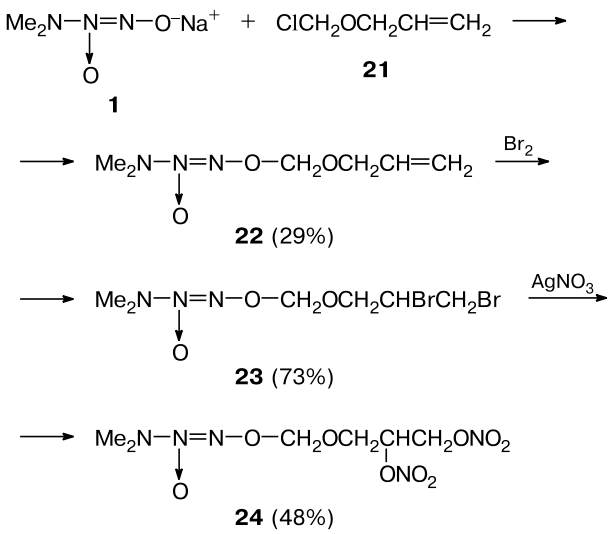
We also studied an alternative possibility of the synthesis of target triazene oxide nitrates depriving potentially dangerous alcohol nitrates in the intermediate steps. First, we used 2-bromopropan-1-ol to synthesize chloromethyl ether **19**. Alkylation of salt **1** with the latter gave the bromine-containing adduct **20** (Scheme 5), whose reaction with silver nitrate in acetonitrile furnished nitrate **15**.

Scheme 5



The reaction of compound **1** with allyl chloromethyl ether **21** gave unsaturated compound **22**. Its bromination led to dibromide **23**. Dinitrate **24** was synthesized by treatment of the latter with an excess of silver nitrate (Scheme 6).

Scheme 6



The structures of compounds obtained were confirmed by spectroscopic data and elemental analysis. The 1-triazene 2-oxides synthesized are promising compounds as hybrid nitrogen monoxide donors.

Experimental

Attention! Special attention should be paid to the work with nitrates, which are high-energy materials requiring careful handling.

IR spectra were obtained on a UR-20 spectrometer. NMR spectra were recorded on a Bruker-AM-300 spectrometer, high resolution spectra were obtained on a Bruker micrOTOF II instrument. Compounds **5** and **21** were obtained according to the described procedures.[6,7]

3,3-Dialkyl-1-hydroxy-1-triazene 2-oxide sodium salts (1—4) (general procedure). Secondary amine (0.34 mmol), sodium methoxide (0.35 mmol), diethyl ether (600 mL), and methanol (90 mL) were placed into a 1-L three-neck flask equipped with a stirrer and reflux condenser with a liquid seal and a gas inlet. A flow of NO was passed through the mixture with vigorous stirring at room temperature over 10—12 h at such a rate that the gas excessive pressure was 13—20 Torr. A dense precipitate formed was filtered off, washed with diethyl ether, dried first on the filter, then *in vacuo* of an oil pump to obtain the corresponding sodium salts **1**—**4**.

Salt **1** (see Ref. 8). The yield was 85%. ^{1}H NMR (DMSO-d_6), δ: 2.71 (s, 6 H, 2 CH_3). IR, ν/cm^{-1}: 3439, 2975, 1608, 1462, 1448, 1385, 1370, 1231, 1198, 956, 945.

Salt **2**. The yield was 78%. ^{1}H NMR (DMSO-d_6), δ: 0.86 (t, 3 H, CH_3); 2.57 (s, 3 H, CH_3); 2.76 (q, 2 H, CH_2). IR, ν/cm^{-1}: 3439, 2975, 1608, 1462, 1448, 1385, 1370, 1246, 1231, 1198, 1179, 956, 945.

Salt **3** (see Ref. 9). The yield was 80%. ^{1}H NMR (DMSO-d_6), δ: 0.88 (t, 6 H, 2 CH_3); 2.76 (q, 4 H, 2 CH_2). IR, ν/cm^{-1}: 3442, 2983, 1606, 1465, 1448, 1385, 1370, 1249, 1233, 1198, 1183, 956, 945.

Salt **4** (see Ref. 10). The yield was 72%. ^{1}H NMR (DMSO-d_6), δ: 3.06 (br.s, 4 H, 2 CH_2); 1.78 (br.s, 4 H, 2 CH_2). IR, ν/cm^{-1}: 2971, 2873, 1464, 1423, 1393, 1224, 1183, 985, 903.

Chloromethyl ethers 6, 7, and 19 (general procedure). A mixture of the corresponding alcohol (31 mmol), 36% aqueous formaldehyde (16 mL), 35% aq. HCl (24 mL), and CH_2Cl_2 (24 mL) was cooled to (−10)—(−5) °C, followed by the in portions addition of $CaCl_2$ (30 g) over 1 h with stirring. The reaction mixture was allowed to stand at −10 °C for 3 h, the organic phase was separated, remaining $CaCl_2$ was washed with CH_2Cl_2, which then was concentrated, the residue was distilled to obtain the products.

1-Chloromethoxy-3-nitroxypropane (6), the yield was 68%. B.p. 80—85 °C (10 Torr.). ^{1}H NMR ($CDCl_3$), δ: 2.1 (m, 2 H, $CH_2\underline{CH_2}CH_2$, J = 6 Hz); 3.8 (t, 2 H, $O\underline{CH_2}CH_2$, J = 6 Hz); 4.6 (t, 2 H, CH_2ON, J = 6 Hz); 5.5 (s, 2 H, $ClCH_2O$).

1-Chloromethoxy-2-nitroxypropane (7), the yield was 50%. ^{1}H NMR ($CDCl_3$), δ: 1.35 (d, 3 H, CH_3); 3.60 (d, 2 H, OCH_2C); 3.65 (m, 1 H, CH, ^1J = 5 Hz, ^2J = 6 Hz); 5.25 (s, 2 H, $ClCH_2O$).

2-Bromo-1-(chloromethoxy)propane (19), the yield was 70%. ^{1}H NMR ($CDCl_3$), δ: 1.75 (d, 3 H, CH_3); 3.80 (d, 2 H, OCH_2); 4.25 (m, 1 H, CH); 5.20 (s, 2 H, $ClCH_2O$).

Alkylation of sodium salts 1—4 with chloromethyl ethers 5—7 (general procedure). Chloromethyl ether **5**—**7** (2 mmol) was added in small portions to a suspension of sodium salt **1**—**4** (2 mmol) in DMF (2 mL) at ~0 °C over 30 min. After addition of the ether, the reaction mixture was warmed up to room temperature and allowed to stand for another 2.5 h. Then, it was poured into water (30 mL) and extracted with dichloromethane (5×5 mL). The combined extracts were washed with water (2×10 mL), dried with sodium sulfate, the drying agent was filtered off, the filtrate was concentrated *in vacuo*. The residue was subjected to chromatography on silica gel to isolate the products.

3,3-Dimethyl-1-[(2-nitroxyethoxy)methoxy]-1-triazene 2-oxide (8), the yield was 46%. ^{1}H NMR ($CDCl_3$), δ: 3.05 (s, 6 H, CH_3); 4.0 (t, 2 H, $O\underline{CH_2}CH_2ON$, J = 4.5 Hz); 4.6 (t, 2 H, $OCH_2\underline{CH_2}ON$); 5.3 (s, 2 H, OCH_2O). ^{14}N NMR, δ: −44.7. IR, ν/cm^{-1}: 2915, 2898, 1633, 1501, 1282, 1024, 970. HRMS, found: m/z 225.0830 $[M + H]^+$; 242.1091 $[M + NH_4]^+$; 247.0640 $[M + Na]^+$; 263.0380 $[M + K]^+$. $C_5H_{12}N_4O_6$. Calculated: 225.0835 $[M + H]^+$; 242.1100 $[M + NH_4]^+$; 247.0654 $[M + Na]^+$; 263.0393 $[M + K]^+$.

3-Ethyl-3-methyl-1-[(2-nitroxyethoxy)methoxy]-1-triazene 2-oxide (9), the yield was 36.2%. ^{1}H NMR ($CDCl_3$), δ: 1.15 (t, 3 H, $\underline{CH_3}CH_2$, J = 7 Hz); 3.0 (s, 3 H, CH_3); 3.40 (q, 2 H, $\underline{CH_3}CH_2$, J = 7 Hz); 4.0 (t, 2 H, $O\underline{CH_2}CH_2ON$, J = 4.5 Hz); 4.65 (t, 2 H, $OCH_2\underline{CH_2}ON$); 5.30 (s, 2 H, OCH_2O). ^{14}N NMR, δ: −44.83. IR, ν/cm^{-1}: 2978, 2942, 2897, 1633, 1500, 1282, 1026, 963. HRMS, found: m/z 239.0995 $[M + H]^+$; 256.1256 $[M + NH_4]^+$; 261.0810 $[M + Na]^+$; 277.0547 $[M + K]^+$. $C_6H_{14}N_4O_6$. Calculated: 239.0992 $[M + H]^+$; 256.1257 $[M + NH_4]^+$; 261.0811 $[M + Na]^+$; 277.0550 $[M + K]^+$.

3,3-Diethyl-1-[(2-nitroxyethoxy)methoxy]-1-triazene 2-oxide (10), the yield was 23%. ^{1}H NMR ($CDCl_3$), δ: 1.2 (t, 6 H, 2 $\underline{CH_3}CH_2$, J = 7 Hz); 3.4 (q, 4 H, 2 $\underline{CH_3}CH_2$, J = 7 Hz); 4.0 (t, 2 H, $O\underline{CH_2}CH_2ON$, J = 4.5 Hz); 4.7 (t, 2 H, $OCH_2\underline{CH_2}ON$, J = 4.5 Hz); 5.2 (s, 2 H, OCH_2O). ^{14}N NMR, δ: −44.27. IR, ν/cm^{-1}: 2981, 2941, 2897, 2881, 1634, 1512, 1282, 963. HRMS, found: m/z 253.1154 $[M + H]^+$; 275.0970 $[M + Na]^+$; 291.0705 $[M + K]^+$. $C_7H_{16}N_4O_6$. Calculated: 253.1148 $[M + H]^+$; 275.0967 $[M + Na]^+$; 291.0707 $[M + K]^+$.

1-[(2-Nitroxyethoxy)methoxy]-3,3-tetramethylene-1-triazene 2-oxide (11), the yield was 51.3%. ^{1}H NMR ($CDCl_3$), δ: 2.0 (m, 4 H, 2 CH_2); 3.60 (m, 4 H, 2 CH_2N); 4.0 (t, 2 H, $O\underline{CH_2}CH_2ON$, J = 4.5 Hz); 4.65 (t, 2 H, $OCH_2\underline{CH_2}ON$, J = 4.5 Hz); 5.25 (s, 2 H, OCH_2O). ^{14}N NMR, δ: −44.49. IR, ν/cm^{-1}: 2963, 2886, 1633, 1486, 1281, 958. HRMS, found: m/z 251.0998 $[M + H]^+$; 268.1259 $[M + NH_4]^+$; 273.0810 $[M + Na]^+$; 289.0543 $[M + K]^+$. $C_7H_{14}N_4O_6$. Calculated: 251.0992 $[M + H]^+$; 268.1257 $[M + NH_4]^+$; 273.0811 $[M + Na]^+$; 289.055 $[M + K]^+$.

3,3-Dimethyl-1-[(3-nitroxypropoxy)methoxy]-1-triazene 2-oxide (12), the yield was 53%. ^{1}H NMR ($CDCl_3$), δ: 2.0 (t, 2 H, $CH_2\underline{CH_2}CH_2$, J = 6.5 Hz); 3.1 (s, 6 H, CH_3N); 3.8 (t, 2 H, $\underline{CH_2}OCH_2O$, J = 6 Hz); 4.55 (t, 2 H, CH_2ON, J = 6 Hz); 5.25 (s, 2 H, OCH_2O). ^{14}N NMR, δ: −43; −55. HRMS, found: m/z 239.0095 $[M + H]^+$; 261.0809 $[M + Na]^+$. $C_6H_{14}N_4O_6$. Calculated: 239.0992 $[M + H]^+$; 261.0811 $[M + Na]^+$.

3-Ethyl-3-methyl-1-[(3-nitroxypropoxy)methoxy]-1-triazene 2-oxide (13), the yield was 32%. ^{1}H NMR ($CDCl_3$), δ: 1.1 (t, 3 H, $\underline{CH_3}CH_2$, J = 7 Hz); 2.0 (t, 2 H, $CH_2\underline{CH_2}CH_2$, J = 6 Hz); 2.9 (s, 6 H, CH_3N); 3.3 (dd, 2 H, CH_2N, J = 6 Hz); 3.85 (t, 2 H, $CH_2\underline{CH_2}O$, J = 6 Hz); 4.5 (t, 2 H, CH_2ON, J = 6 Hz); 5.2 (s, 2 H, OCH_2O). IR, ν/cm^{-1}: 2941, 1631, 1500, 1281. HRMS, found: m/z 253.1173 $[M + H]^+$; 275.0965 $[M + Na]^+$. $C_7H_{16}N_4O_6$. Calculated: 253.1148 $[M + H]^+$; 275.0967 $[M + Na]^+$.

1-[3-(Nitroxypropoxy)methoxy]-3,3-tetramethylene-1-triazene 2-oxide (14), the yield was 42%. ^{1}H NMR ($CDCl_3$), δ: 1.8 (m, 6 H, $\underline{CH_2}$ + $CH_2\underline{CH_2}CH_2$, ^1J = 6.5 Hz, ^2J = 6 Hz); 3.5 (t, 4 H, CH_2N, J = 6 Hz); 3.75 (t, 2 H, $CH_2\underline{CH_2}O$, J = 6.5 Hz); 4.5 (t, 2 H, CH_2ON, J = 6.5 Hz); 5.3 (s, 2 H, OCH_2O). ^{14}N NMR, δ: −42.57; −53.25. HRMS, found: m/z 265.1146 $[M + H]^+$, 287.0966 $[M + Na]^+$. $C_8H_{16}N_4O_6$. Calculated: 265.1148 $[M + H]^+$; 287.0968 $[M + Na]^+$.

3,3-Dimethyl-1-[(2-nitroxypropoxy)methoxy]-1-triazene 2-oxide (15). ***A.*** The yield was 40%. ^{1}H NMR ($CDCl_3$), δ: 1.35 (d, 3 H, $CH\underline{CH_3}$, J = 5 Hz); 3.0 (s, 6 H, CH_3N); 3.75 (m, 2 H, $\underline{CH_2}CH_2O$, J = 6 Hz); 5.2 (s, 2 H, OCH_2O); 5.25 (m, 1 H, $CH_2\underline{CH}CH_3$, J = 6 Hz). HRMS, found: m/z 239.0991 $[M + H]^+$; 261.0808 $[M + Na]^+$. $C_6H_{14}N_4O_6$. Calculated: 239.0992 $[M + H]^+$; 261.0811 $[M + Na]^+$. Found (%): C, 30.29; H, 5.97; N, 23.48. $C_6H_{14}N_4O_6$. Calculated (%): C, 30.25; H, 5.92; N, 23.52.

B. A mixture of compound **20** (0.2 g, 0.7 mmol) and $AgNO_3$ (0.15 g, 0.8 mmol) was refluxed in anhydrous MeCN (5 mL) for 3 h. The solvent was evaporated, the residue was diluted with

$CHCl_3$, a precipitate was filtered off, the filtrate was concentrated. The residue was subjected to chromatography on silica gel to isolate product **15** in 71% yield, which was identical to the substance obtained above.

1-[(2-Nitroxypropoxy)methoxy]-3,3-tetramethylene-1-triazene 2-oxide (16), the yield was 35%. ^{1}H NMR ($CDCl_3$), δ: 1.35 (d, 3 H, $\underline{CH_3}CH$, J = 5 Hz); 1.90 (s, 4 H, $CH_2\underline{CH_2}$); 3.50 (s, 4 H, CH_2N); 3.75 (m, 2 H, $CH\underline{CH_2}O$); 5.20 (m, 3 H, OCH_2O); 5.25 (m, 3 H, $CH_2\underline{CH}CH_2$, J = 6 Hz). HRMS, found: m/z 265.1146 $[M + H]^+$; 287.0966 $[M + Na]^+$. $C_8H_{16}N_4O_6$. Calculated: 265.1148 $[M + H]^+$; 287.0968 $[M + Na]^+$.

Disodium 3,7-dimethyl-1,2,3,7,8,9-hexaazanona-1,8-diene-1,9-diolate 2,8-dioxide (17) (see Ref. 11). N^1,N^3-Dimethyl-1,3-diaminopropane (4.09 g, 0.04 mol), sodium methoxide (4.32 g, 0.04 mol), diethyl ether (150 mL), and methanol (20 mL) were placed into a three-neck flask equipped with a stirrer, a reflux condenser with a liquid seal and a gas inlet. A flow of NO was passed with vigorous stirring at room temperature for 10—12 h at such a rate that the gas excessive pressure was 13—20 Torr. A dense precipitate formed was filtered off, washed with diethyl ether, dried first on the filter, then *in vacuo* of an oil pump to obtain the product **17** (8.8 g, 82%). ^{1}H NMR (DMSO-d_6), δ: 1.21 (m, 2 H, $CH_2\underline{CH_2}CH_2$); 2.55 (s, 6 H, 2 CH_3); 2.76 (m, 4 H, $\underline{CH_2}CH_2\underline{CH_2}$). IR, ν/cm^{-1}: 3441, 2965, 1609, 1463, 1380, 1369, 1246, 1229, 957, 933.

8,12-Dimethyl-1,19-dinitroxy-3,5,15,17-tetraoxa-6,7,8,12,13,14-hexaazanonadeca-6,13-diene 7,13-dioxide (18). Chloromethyl ether **5** (4 mmol) was added in small portions to a suspension of sodium salt **17** (2 mmol) in DMF (4 mL) at ~0 °C over 30 min. After the addition, the reaction mixture was warmed up to room temperature and allowed to stand for another 2.5 h, then poured into water (30 mL) and extracted with dichloromethane (5×5 mL). The combined extracts were washed with water (2×10 mL), dried with sodium sulfate, the drying agent was filtered off, the filtrate was concentrated *in vacuo*. The residue was subjected to chromatography on silica gel to isolate product **18** in 18% yield as an oil. ^{1}H NMR ($CDCl_3$), δ: 2.0 (m, 2 H, $CH_2\underline{CH_2}CH_2$); 2.95 (s, 3 H, CH_3); 3.05 (s, 3 H, CH_3); 3.9 (t, 4 H, 2 $\underline{CH_2}CH_2\underline{CH_2}$, J = 4.5 Hz); 4.2 (m, 4 H, 2 $O\underline{CH_2}CH_2ON$); 4.6 (t, 4 H, 2 $OCH_2\underline{CH_2}ON$, J = 3.6 Hz); 5.2 (s, 4 H, 2 OCH_2O). ^{14}N NMR, δ: –43.86. HRMS, found: m/z 461.1580 $[M + H]^+$; 478.1844 $[M + NH_4]^+$; 483.1392 $[M + Na]^+$; 499.1140 $[M + K]^+$. $C_{11}H_{24}N_8O_{12}$. Calculated: 461.1591 $[M + H]^+$; 478.1857 $[M + NH_4]^+$; 483.1411 $[M + Na]^+$; 499.1151 $[M + K]^+$.

1-[(2-Bromopropoxy)methoxy]-3,3-dimethyl-1-triazene 2-oxide (20). Chloromethyl ether **19** (0.3 g, 1.6 mmol) was added to a mixture of compound **1** (0.2 g, 1.6 mmol) in DMF (5 mL) with stirring at room temperature. After 4 h, the mixture was diluted with water (10 mL), extracted with dichloromethane (3×5 mL), the extract was concentrated *in vacuo*. The residue was subjected to chromatography on silica gel to isolate product **20** as an oil, the yield was 34%. ^{1}H NMR ($CDCl_3$), δ: 1.7 (d, 3 H, $\underline{CH_3}CH$, J = 5 Hz); 3.15 (s, 6 H, 2 CH_3); 3.85 (m, 2 H, $\underline{CH_2}CH$, J = 5.5 Hz); 4.4 (m, 1 H, CH, ^1J = 5 Hz, ^2J = 5.5 Hz); 5.3 (s, 2 H, OCH_2O).

1-Allyloxymethoxy-3,3-dimethyl-1-triazene 2-oxide (22). Chloromethyl ether **21** (0.21 g, 2 mmol) (see Ref. 7) was added in small portions to a suspension of sodium salt **1** (0.25 g, 2 mmol) in DMF (2 mL) at ~0 °C over 30 min. Then the reaction mixture was warmed-up to room temperature and allowed to stand for another 1.5 h, then poured into water (30 mL) and extracted with dichloromethane (5×5 mL). The combined extracts were washed with water (2×10 mL) and dried with sodium sulfate. The drying agent was filtered off, the liquid was concentrated *in vacuo*, the residue was subjected to chromatography on silica gel to isolate product **22** as an oil, the yield was 0.1 g (29%). ^{1}H NMR ($CDCl_3$), δ: 3.1 (s, 6 H, CH_3); 4.2 (d, 2 H, CH_2, J = 5.6 Hz); 5.25 (m, 2 H, CH_2); 5.3 (s, 2 H, OCH_2O); 5.9 (m, 1 H, CH).

1-[(2,3-Dibromopropoxy)methoxy]-3,3-dimethyl-1-triazene 2-oxide (23). Bromine (0.7 g, 4.5 mmol, 0.22 mL) was added in small portions to a solution of compound **22** (0.5 g, 2.8 mmol) in dichloromethane (10 mL) with stirring at temperature below 0 °C, and the mixture was allowed to stand at 10 °C for 24 h, then washed with saturated aqueous sodium thiosulfate, dried with sodium sulfate, the drying agent was filtered off, the solvent was evaporated. The residue was subjected to chromatography on silica gel to isolate product **23** as an oil, the yield was 0.7 g (73%). ^{1}H NMR ($CDCl_3$), δ: 3.05 (s, 6 H, CH_3); 3.8 (d, 2 H, OCH_2CH, J = 6.9 Hz); 4.1 (m, 2 H, $BrCH_2$, ^1J = 6.6 Hz, ^2J = 4.6 Hz); 4.3 (m, 1 H, CH); 5.3 (dd, 2 H, OCH_2O, ^1J = 7.6 Hz, ^2J = 4.0 Hz).

3,3-Dimethyl-1-[(2,3-dinitroxypropoxy)methoxy]-1-triazene 2-oxide (24). A mixture of compound **23** (0.7 g, 2.1 mmol), silver nitrate (2.14 g, 12.6 mmol), and dry acetonitrile (10 mL) was stirred at 60 °C for 40 h without exposure to light. A precipitate was filtered off, the solvent was evaporated *in vacuo*. The residue was subjected to chromatography on silica gel to isolated product **24** as an oil, the yield was 0.3 g (48%). ^{1}H NMR ($CDCl_3$), δ: 3.2 (s, 6 H, CH_3); 4.0 (d, 2 H, CH_2); 4.75 (m, 2 H, CH_2); 5.25 (s, 2 H, OCH_2O); 5.45 (m, 1 H, CH). ^{14}N NMR, δ: –47.9. ^{13}C NMR, δ: 42.35 (CH_3), 65.90 (OCH_2), 68.97 (CH_2ONO_2), 77.29 (CH), 96.18 (OCH_2O). IR, ν/cm^{-1}: 2917, 1645, 1500, 1272, 972. HRMS, found: m/z 322.0610 $[M + Na]^+$; 338.0341 $[M + K]^+$. $C_6H_{13}N_5O_9$. Calculated: 322.0611 $[M + Na]^+$; 338.035 $[M + K]^+$. Found (%): C, 24.06; H, 4.33; N, 23.51. $C_6H_{13}N_5O_9$. Calculated (%): C, 24.09; H, 4.38; N, 23.41.

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Received April 11, 2013;
in revised form September 25, 2013