

ADAMANTYLAZOLES.

ACID-CATALYZED ADAMANTYLATION OF 1,2,4-TRIAZOLES

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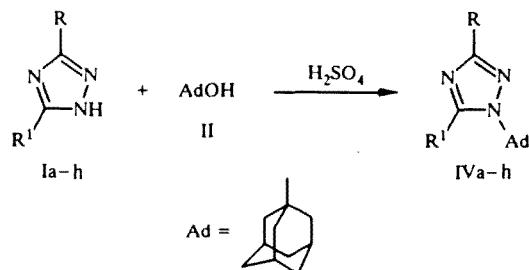
The reaction of 1-adamantanol with 1,2,4-triazole in sulfuric acid forms 1-adamantyl derivatives. In boiling chloroform containing traces of sulfuric acid, a mixture of isomeric N-adamantyl-1,2,4-triazoles is obtained. It is shown that 1-adamantyl carbocation is formed at a sulfuric acid concentration above 70%.

Several publications [1, 2] are devoted to the alkylation of 1,2,4-triazoles. The alkylating agents used were haloalkanes and their derivatives [1-7], alkyl sulfates [6], oxiranes [8-11], compounds with an activated multiple bond [8, 12, 13], and diazomethane [6]. Alkylation of triazoles is usually carried out in organic solvents (acetone, dioxane, DMFA), in the presence of bases or excess triazole [3-7, 14], often under phase-transfer catalysis conditions [14-17]. The ratio of isomeric N-alkyltriazoles formed during the alkylation is strongly dependent on the nature of the substituents at the C₍₃₎ and C₍₅₎ carbon atoms of the triazole ring [3, 6, 18-20], state of the substrate (anion or neutral molecule [6, 7, 14]), and nature of the alkylating agent. Thus, alkylation of 3-nitro-1,2,4-triazoles by haloalkanes in the presence of bases [6] and by oxiranes [8-10] is directed almost exclusively at the N-1 position. At the same time, alkylation of nitrotriazoles by diazomethane [6] or dimethylformamide dimethylacetal [21] takes place less selectively — a mixture of three possible isomers is formed in which the 1-substituted compound predominates. In 1,2,4-triazoles containing donor substituents (CH₃, NH₂) at the ring carbon atoms, alkylation is usually associated with formation of mixtures of isomeric N-alkyltriazoles [3, 18-20]. A definite role in alkylation is also played by the steric effects of the substituents in the 3(5) positions of the triazole ring [20].

Alkylation of 1,2,4-triazoles in acid media has received little attention. It was shown earlier that adamantylation of 3(5)-R-1,2,4-triazoles (I) by 1-adamantanol (II), 1-nitroxyadamantane (III) or 1-bromoadamantane [22] can be achieved in sulfuric acid medium. The reaction takes place at room temperature and usually goes to completion in 2 to 3 h.

Continuing the initiated study, we investigated the influence of R substituents in triazole I and of the acidity of the medium on the direction of the reaction. The reaction of adamantanol II with triazoles I containing the electron-acceptor substituents 3(5)-nitro-1,2,4-triazole (Ia) ($pK_{BH^+} - 4.5$ [23]) and 3(5)-trifluoroacetamido-1,2,4-triazole (Ib) takes place smoothly in 96% sulfuric acid with formation, respectively, of 1-(1-adamantyl)-3-nitro-1,2,4-triazole (IVa) and 1-(1-adamantyl)-3-trifluoroacetamido-1,2,4-triazole (IVb). Similarly, from 3-nitro-5-bromo-1,2,4-triazole (Ic) ($pK_{BH^+} - 6.2$, calculated by extrapolation from [24]) we obtained 1-(1-adamantyl)-3-nitro-5-bromo-1,2,4-triazole (IVc), and from 3-nitro-5-methyl-1,2,4-triazole (Id) ($pK_{BH^+} - 4.2$ [23]) we obtained 1-(1-adamantyl)-3-methyl-5-nitro-1,2,4-triazole (IVd). Adamantylation of the stronger bases 3(5)-chloro-1,2,4-triazole (Ie) ($pK_{BH^+} 1.2$ [25]), 1,2,4-triazole (If) ($pK_{BH^+} 2.45$ [25]), and 3(5)-methyl-1,2,4-triazole (Ig) ($pK_{BH^+} 3.28$ [25]) takes place definitively in 85% sulfuric acid. Adamantylation of 3(5)-amino-1,2,4-triazole (Ih) ($pK_{BH^+} 4.04$ [25]) is best carried out in 75% sulfuric acid. Thus were obtained 1-(1-adamantyl)-3-chloro-1,2,4-triazole (IVe), 1-(1-adamantyl)-1,2,4-triazole (IVf), 1-(1-adamantyl)-3-methyl-1,2,4-triazole (IVh). Similarly, compounds IIIa-h also can be obtained with 1-nitroxy- or 1-bromoadamantane.

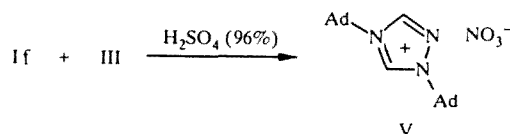
St. Petersburg State Technological Institute, St. Petersburg 198013. N. D. Zelinskii Institute of Organic Chemistry, Russian Academy of Sciences, Moscow 117913. Translated from *Khimiya Geterotsiklicheskii Soedinenii*, No. 8, pp. 1078-1087, August, 1996. Original article submitted June 7, 1996.



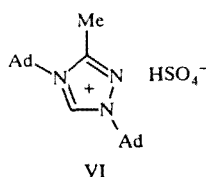
I, IV a R = NO₂, R¹ = H [22]; b R = NHCOCF₃, R¹ = H [22]; c R = NO₂, R¹ = Br; d R = NO₂, R¹ = CH₃; e R = Cl, R = Cl, R¹ = H; f R = R¹ = H; g R = CH₃, R¹ = H; h R = NH₂, R¹ = H

Under all the indicated conditions, the reaction takes place strictly regiospecifically — no other isomers were detected. The structure of the synthesized compounds was proven by comparing the calculated and experimental values of the dipole moments and by means of ESR and ¹³C NMR spectra.

Adamantylation of triazole If with nitroxyadamantane III in 96% sulfuric acid led to the formation of 1,4-bis(1-adamantyl)-1,2,4-triazolium nitrate (V). The same compound was obtained by reacting compound IVa with nitroxyadamantane III in 96% sulfuric acid. The asymmetric structure of compound V was confirmed by the appearance of two proton signals in the ESR spectrum (see Table 2). Interestingly, compound V is not formed with adamantanol II, i.e., triazolium cation V is not stabilized by sulfate ion.



Methyltriazole Ig with adamantanol II in 96% sulfuric acid forms 1,4-bis(1-adamantyl)-3-methyl-1,2,4-triazolium bisulfate (VI).



Adamantylation of triazoles I was carried out in 85-96% sulfuric acid solutions whose acidity function ($-H_0 = 8.29-9.88$) was several orders of magnitude greater than the pK_{BH^+} values of the corresponding triazoles. It was natural to assume that the reaction involves the protonated form of the triazoles. It was shown previously that tetrazole is alkylated by tert-butanol in sulfuric acid or in boiling chloroform in the presence of a few drops of sulfuric acid [26]. Assuming that the acidity of the latter system would be moderate, we attempted to use it to carry out the adamantylation of the nonprotonated form of the azoles. It was found that the reaction in chloroform with the more highly basic triazoles If,g has the same course as in 85% sulfuric acid, i.e., with the formation of compounds IVf,g. Adamantylation of 3,5-disubstituted triazoles Ic and Id had a difference course. After prolonged heating of compound Id in chloroform, only traces of compound IVd were obtained. The main product of the reaction is 1-(1-adamantyl)-3-methyl-5-nitro-1,2,4-triazole (VIIa).

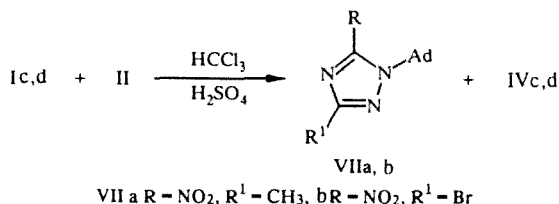


TABLE 1. Dipole Moments of N-(1-Adamantyl)-R-1,2,4-triazoles

R	μ , calculated (D)			μ , exp (D)
	1-(1-adamantyl)-3-R-1,2,4-triazole	1-(1-adamantyl)-5-R-1,2,4-triazole	4-(1-adamantyl)-3-R-1,2,4-triazole	
H	—	—	6,99	4,60
NO ₂	7,70	3,79	7,27	7,56
CH ₃	3,40	3,01	7,45	3,30
Cl	5,30	2,74	6,98	5,27

TABLE 2. ESR and IR Data of Synthesized Compounds

Compound	Empirical formula	ESR spectrum, δ , ppm (CDCl ₃)	IR spectrum, cm ⁻¹
IVa	C ₁₂ H ₁₆ N ₄ O ₂	8,19 (1H, s), 2,13 (br. s), 2,10 (br. s), 1,69 (br. s) (15H, Ad)	
IVc	C ₁₂ H ₁₅ BrN ₄ O ₂	2,18 (br. s), 2,1 (br. s), 1,53 (br. s) (15H, Ad)	1548, 1484 (C—NO ₂), 1408, 1304, 840, 686
IVd	C ₁₃ H ₁₈ N ₄ O ₂	2,54 (3H, s), 2,12 (br. s), 2,10 (br. s), 1,59 (br. s) (15H, Ad)	
IVe	C ₁₂ H ₁₆ ClN ₃	7,85 (1H, s), 1,98 (br. s), 1,88 (br. s), 1,50 (br. s) (15H, Ad)	1500, 1470, 1380, 1310
IVf	C ₁₂ H ₁₇ N ₃	7,77 (1H, s), 7,49 (1H, s), 1,80 (br. s), 1,75 (br. s), 1,35 (br. s) (15H, Ad)	
IVg	C ₁₃ H ₁₉ N ₃	7,30 (1H, s), 1,56 (3H, s), 1,35 (br. s), 0,97 (br. s) (15H, Ad)	
IVh	C ₁₂ H ₁₈ N ₄	7,90 (1H, s), 4,98 (2H, br. s), 2,13 (br. s), 2,03 (br. s), 1,70 (br. s) (15H, Ad)	2880...2820, 1630, 1550, 1390, 1200
V	C ₂₂ H ₃₂ N ₃ ·NO ₃	10,6 (1H, s), 9,5 (1H, s), 2,3 (br. s), 1,8 (br. s) (15H, Ad)	2800...2730, 1350 (NO ₃ ⁻)
VI	C ₂₃ H ₃₄ N ₃ ·HSO ₄	8,8 (1H, s), 2,5 (3H, s), 1,9...2,00 (br. s), 1,5 (br. s) (30H, 2Ad)*	2800...2730, 1270 (HSO ₄ ⁻)
VIIa	C ₁₃ H ₁₈ N ₄ O ₂	2,32 (3H, s), 2,21 (br. s), 1,70 (br. s) (15H, Ad)	
VIIb	C ₁₂ H ₁₅ BrN ₄ O ₂	2,24 (br. s), 1,73 (br. s) (15H, Ad)	1540, 1480, 1320, 1264, 816, 744
VIIc	C ₁₂ H ₁₆ N ₄ O ₂	7,78 (1H, c), 2,23 (br. s), 1,72 (br. s) (15H, Ad)	
VIII	C ₂₂ H ₃₁ N ₃ O	7,4 (1H, s), 2,25 (br. s), 1,8 (br. s) (15H, Ad)	2944, 2896, 1664 (C=O), 1456, 1312, 848
IX	C ₂₂ H ₃₀ N ₄ O ₃	2,30 (br. s), 1,70 (br. s) (15H, Ad)	2944, 2880, 1708 (C=O), 1600, 1536, 1336 (C—NO ₂), 1303

*Solvent CF₃COOH.

Adamantylation of compound Ic in chloroform led to the formation of a mixture of adamantyltriazole (IVc) and its isomer, 1-(1-adamantyl)-3-bromo-5-nitro-1,2,4-triazole (VIIb), and the fraction of the latter increased as the amount of added sulfuric acid decreased.

Adamantylation of compound Ia in chloroform is more complex. By boiling equimolar amounts of triazole Ia and adamantanol II in chloroform containing 0.6% sulfuric acid, we obtained a mixture of four products, from which we isolated chromatographically on silica gel the compound IVa (8% yield), 1-(1-adamantyl)-5-nitro-1,2,4-triazole (VIIc) (11% yield), 1,2-bis(1-adamantyl)-1,2,4-triazol-3-one VIII (24% yield), and 1,2-bis(1-adamantyl)-3-nitro-1,2,4-triazol-5-one IX (11% yield).

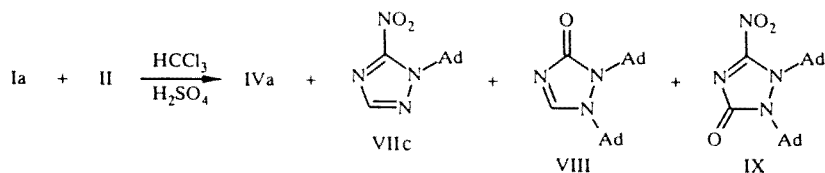


TABLE 3. Data of ^{13}C NMR Spectra of Synthesized Compounds

Compound	Carbon atom	Chemical shifts of ^{13}C (ppm), SSCC of ^{13}C , ^1H (Hz)
IVa	C(3)	162,46 d, $^3J_{\text{C,H-5}} = 11,0$
	C(5)	141,27 d, $^1J_{\text{C,H-5}} = 215,8$
	1-Ad	29,17 s, 35,44 s, 42,06 s, 61,38 s
IVc	C(3)	160,10 br. s
	C(5)	126,08 s
	1-Ad	28,53 s, 35,35 s, 41,64 s, 56,17 s
IVd	C(3)	159,64 br. s
	C(5)	153,46 q, $^2J_{\text{C,3-CH}_3} = 7,8$
	5-CH ₃	15,854 q, $^1J_{\text{C,H}} = 131,1$
	1-Ad	29,24 s, 35,17 s, 41,20 s, 63,32 s
IVe	C(3)	150,82 d, $^3J_{\text{C,H-5}} = 15,1$
	C(5)	140,11 d, $^1J_{\text{C,H-5}} = 211,5$
	1-Ad	28,65 s, 35,14 s, 41,54 s, 58,94 s
IVf	C(3)	150,29 d, $^1J_{\text{C,H-3}} = 205,3$, $^3J_{\text{C,H-5}} = 12,1$
	C(5)	138,53 d, $^1J_{\text{C,H-5}} = 208,6$, $^3J_{\text{C,H-3}} = 7,4$
	1-Ad	28,56 s, 35,16 s, 41,74 s, 57,48 s
IVg	C(3)	158,34 d, q, $^2J_{\text{C,3-CH}_3} = 7,0$, $^3J_{\text{C,H-5}} = 11,4$
	C(5)	137,96 d, $^1J_{\text{C,H-5}} = 204,9$
	3-CH ₃	12,43 q, $^1J_{\text{C,H}} = 127,9$
	1-Ad	27,85 s, 34,49 s, 40,98 s, 56,13 s
IVh	C(3)	162,97 d, $^3J_{\text{C,H-5}} = 13,1$
	C(5)	138,11 d, $^1J_{\text{C,H-5}} = 205,53$
	1-Ad	29,13 s, 34,90 s, 40,35 s, 65,52 s
VIIa	C(3)	157,11 q, $^2J_{\text{C,3-CH}_3} = 7,8$
	C(5)	151,62 br. s
	3-CH ₃	13,88 q, $^1J_{\text{C,H}} = 128,7$
	1-Ad	29,72 s, 35,64 s, 41,02 s, 64,63 s
VIIb	C(3)	135,69 s
	C(5)	151,34 br. s
	1-Ad	29,35 s, 35,11 s, 40,60 s, 66,56 s
VIIc	C(3)	147,60 d, $^1J_{\text{C,H-3}} = 213,3$
	C(5)	152,15 d, $^3J_{\text{C,H-3}} = 4,3$
	1-Ad	29,60 s, 35,49 s, 41,90 s, 65,29 s

TABLE 4. Data of ^{14}N NMR Spectra of Synthesized Compounds

Compound	Nitrogen atom	Chemical shifts of ^{14}N (ppm) and signal halfwidth (Hz)
IVa	N-1	-135,22, $\nu_{1/2} = 600$
	3-NO ₂	-27,54, $\nu_{1/2} = 140$
IVc	3-NO ₂	-29,74, $\nu_{1/2} = 145$
VIIb	5-NO ₂	-27,08, $\nu_{1/2} = 35$
VIIc	N-1	-155,95, $\nu_{1/2} = 250$
	5-NO ₂	-24,03, $\nu_{1/2} = 35$

Compound IVa is apparently formed in the same way as in sulfuric acid, as the result of adamantylation of the protonated form of triazole Ia. Characteristically, as the sulfuric acid content of the chloroform increases from 0.02% to 1.3%, the yield of compound IVa (and also of compound IX) increases. It may be postulated that compound VIIc as a result of adamantylation of the nonprotonated form of triazole Ic, and also compound VIId ($\text{R} = \text{NO}_2$, $\text{R}^1 = \text{Me}$) are formed from triazole Id. Triazolone VIII may be formed as a result of hydrolysis of the 1,2-bis(1-adamantyl)-3-nitro-1,2,4-triazol-3-one (1650 cm^{-1}) and 1,3,4-trimethyl-1,2,4-triazol-5-one (1710 cm^{-1}) [27].

Adamantylation of compound Ia in boiling chloroform can also be carried out in the presence of phosphoric acid, but in that case there is only formed a mixture of compounds IVa and VIIc — triazolones VIII and IX could not be detected. It

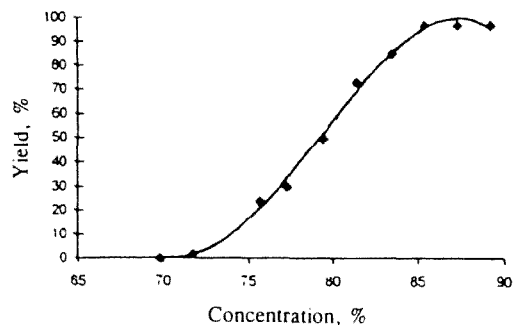
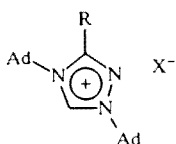


Fig. 1. Yield of 1-(1-adamantyl)-3-nitro-1,2,4-triazole IIIa vs. sulfuric acid concentration.

may be assumed that in the presence of the weaker phosphoric acid, the content of 1-adamantylcarbocation (%) is lower, and no diadamantyltriazolones are formed. A good analogy is the adamantylation of triazoles If,g, which form diadamantyltriazolinium salts XIa and XIb, respectively, in 96% sulfuric acid, whereas they cannot be observed in 85% sulfuric acid.



XIa, b
XI a R = H, X = NO₃; b R = Me, X = HSO₄

We studied the influence of sulfuric acid concentration on the adamantylation reactions. As is well known, adamantanol II and also nitroxoadamantane III and 1-bromoadamantane in acids tend to form adamantylcarbocation X [28, 29]. The ESR and ¹³C NMR spectra of carbocation X in superacids were studied in [30]. The formation of this carbocation in sulfuric acid is widely used in synthetic practice to prepare adamantanone [31, 32], 1-acetylaminoadamantane [33], and other derivatives. However, the literature lacks data on the influence of sulfuric acid concentration on the formation of carbocation X.

The influence of sulfuric acid concentration on the adamantylation reaction was studied on nitrotriazole Ia, taken as an example. A number of preparative experiments were set up to prepare compound IVa in 75.7-89.2% sulfuric acid under identical conditions (equimolar ratio of compounds IIa and Ia; reaction temperature, 20 ± 1°C; reaction time, 5 h). On completion of the reaction, the content of adamantyltriazole IVa was determined by the VELC method.

As is evident from Fig. 1, the dependence of the yield of compound IIIa on sulfuric acid concentration has a typical S shape, and the yield increases with sulfuric acid concentration. Because of the insufficient solubility of adamantanol II, we were unable to set up identical experiments in sulfuric acid with a concentration below 75.7%. Using TLC, in experiments with 71.7% sulfuric acid (in which adamantanol exhibits limited solubility), we qualitatively detected only traces of compound IVa. In 69.8% sulfuric acid, no indications of the formation of compound IVa could be detected. The data obtained cannot be considered quantitative; nevertheless they confirm that, first, the adamantylation reaction involves the protonated form of triazole Ia, and second, 1-adamantylcarbocation X is apparently formed in sulfuric acid of concentration above 70%.

The structure of the adamantyltriazoles obtained was proved by measuring their dipole moments (compounds IVa,e,g), and also with the aid of NMR spectra of ¹H, ¹³C, and ¹⁴N. The experimentally obtained dipole moments were compared with the calculated values for the three possible isomers (Table 1).

The calculation of the dipole moments was carried out by using the vector additive scheme [34] allowing for molecular geometry: for compounds IVa and IVf — from x-ray diffraction studies [35, 36]; for compound IVe, a geometry analogous to that of compound IVa was assumed. The contributions of the NO₂, Cl, and CH₃ groups were taken from [37]. The contribution of the adamantyl fragment was calculated on the basis of the experimental dipole moment of compound IVf, whose structure was definitively proved by spectral data. According to our calculations, μ_{Ad} = 1.5 D. This method is considered more legitimate than the use of μ_{Ad} values cited in the literature [38].

The value of experimental dipole moments for compounds IVa,e,g in good agreement with the values calculated for 1-(1-adamantyl)-3-R-1,3,4-triazoles and differ appreciably from the calculated dipole moments of the 1-(1-adamantyl)-5-R and 4-(1-adamantyl)-3-R isomers (Table 1). This indicates that the adamantylation products are 1-(1-adamantyl)-3-R-substituted 1,2,4-triazoles.

The ESR spectra contain signals of monosubstituted adamantane as well as signals of the triazole ring, methyl group, and amino groups. More important information on the structure of N-adamantyltriazoles is provided by the parameters of ^{13}C NMR spectra: the chemical shifts of ^{13}C , as well as direct and long-range SSCC of ^{13}C , ^1H .

The ESR spectrum of compound IVf contains two signals of ring protons, and the ^{13}C NMR spectrum contains two signals with chemical shifts of 150.3 ppm and 138.5 ppm in the form of a doublet of doublets; this clearly indicates that adamantyl is located at N-1, not N-4.

In 3,5-disubstituted N-adamantyl-1,2,4-triazoles IVc,d with a nitro group in the 3 position, in N-adamantyl-3-nitro-1,2,4-triazole IVa and N-adamantyl-3-substituted 1,2,4-triazoles in the presence of an electron-donor substituent (between two nitrogen atoms of the pyridine type ring, in the sp^2 hybrid state), the difference of chemical shifts C_3-C_5 is 7-24 ppm. If, however, as in compounds VIIa,b, the nitro group is located in the 5 position (between nitrogen atoms of the pyridine and pyrrole type ring), this difference is $-16+6$ ppm, which is due to the different electronegativity of the N-1 and N-2 atoms of the triazole ring. Such a structure of the compounds is also indicated by the SSCC of ^{13}C , ^1H . The vicinal SSCC $^3J_{\text{C-3,H-5}}$ in compounds IVa and IVe-h range from 4.3 to 7.4 Hz. Earlier, we observed analogous patterns in the variation of the chemical shifts of ^{13}C and of SSCC of ^{13}C , ^1H in N-acetyl-substituted nitro-1,2,4-triazoles [39]. In the presence of a methyl group (compounds IVd,g, VIIa), the chemical shifts of its signal in the 3 position are smaller (1.42-13.9 ppm) than in the 5 position (15.9 ppm).

The presence of nitro groups in the 3 or 5 position of the thiazole ring is indicated both by a signal broadening of the ring carbon atom carrying a nitro group, and by the presence of broadened signals of ^{14}N with a signal halfwidth $\nu_{1/2}$ ranging from 35 Hz to 140 Hz and the chemical shifts of these signals amounting to -24 ppm to -30 ppm.

EXPERIMENTAL

The IR spectra were recorded on an UR-20 spectrometer in Vaseline oil or in KBr pellets. The ESR spectra of compounds V, VI, VIII, and IX (in CDCl_3) were recorded on a Perkin-Elmer R-12 instrument (60 MHz), with HMDS as the internal standard, and the ^1H , ^{13}C and ^{14}N NMR spectra of compounds IVc-h, VIIa-c were recorded on an AM-300 Bruker instrument with operating frequencies of 300, 133, 75, 47, and 21 MHz, respectively, in CDCl_3 at a solution concentration of 3-5 mole/liter. All the spectra were recorded by pulsed spectroscopy with accumulation of the spectra (for ^1H — 32-64 pulses, for ^{13}C — 500-3500 pulses and for ^{14}N — 20,000-25,000 pulses, depending on the concentration of the substance and the objectives of the experiment) and a subsequent Fourier transformation. The ^{13}C NMR spectra were recorded with wideband decoupling from protons, by means of selective transfer and polarization [^1H] $\rightarrow$ ^{13}C (INEPT and SPT regimes). The measurement accuracy of the ^1H , ^{13}C chemical shifts was ± 0.025 ppm, that of ^{14}N chemical shifts was ± 0.5 ppm, and that of the SSCC of ^1H , ^1H and ^{13}C , ^1H was $-0.1-0.5$ Hz, depending on the objectives of the experiment.

The ultimate analysis was carried out with a Hewlett-Packard 185B analyzer. The dipole moments were measured with a Tangens-2M dielcometer in dioxane at 25°C . TLC was carried out on UV-254 Silufol plates, chloroform was used as the eluent, and the development was done with ultraviolet irradiation or iodine vapor. Separation by liquid chromatography was carried out on Chemapol silica gel, 100/250 μ , with chloroform as the eluent.

In experiments aimed at determining the dependence of the yield of 1-(1-adamantyl)-3-nitro-1,2,4-triazole IVa on sulfuric acid concentration, the yield was determined by multiplying the mass of the sample, obtained by treating the reaction mixture, by its content of end product IVa. This content was determined by VELC on a Laboratorni Pistroje chromatograph, the support was SPHC₁₈ silasorb, the column was 3×250 mm, the mobile phase was 1:1 $\text{CH}_3\text{CN}-\text{H}_2\text{O}$, a UV detector with a 254 nm was used, and the internal standard was 1,3,5-trinitrobenzene.

1-(1-Adamantyl)-5-bromo-3-nitro-1,2,4-triazole (IVc). A mixture of 0.48 g (2.5 mmole) of 5-bromo-3-nitro-1,2,4-triazole Ic and 0.38 g (2.5 mmole) of 1-adamantanol II in 25 ml of sulfuric acid is kept at room temperature for 18 h. The reaction mixture is decanted into 250 ml of water, and the precipitate is filtered off. Yield, 0.62 g (76%), mp $211-212^\circ\text{C}$ (ethyl acetate), R_f 0.30. Found, %: C 44.40, H 4.96, N 17.45. $\text{C}_{12}\text{H}_{15}\text{BrN}_4\text{O}_2$. Calculated, %: C 44.05, H 4.63, N 17.13.

1-(1-Adamantyl)-5-methyl-3-nitro-1,2,4-triazole (IVd). A mixture of 0.64 g (5.0 mmole) of 5-methyl-3-nitro-1,2,4-triazole Id and 0.76 g (5.0 mmole) of 1-adamantanol II in 25 ml of sulfuric acid is kept for 2 h at room temperature. The reaction mass is decanted into 250 ml of water, and the precipitate is filtered off. Yield, 0.96 g (73%), mp 166-167°C (ethanol), R_f 0.3. Found, %: C 58.97, H 6.35, N 21.70. $C_{13}H_{18}N_4O_2$. Calculated, %: C 59.51, H 6.93, N 21.36.

1-(1-Adamantyl)-3-chloro-1,2,4-triazole (IVe). To a solution of 0.65 g (2.7 mmole) of 3(5)-chloro-1,2,4-triazole Ie in 12 ml of 85% sulfuric acid is added 1.06 g (7.1 mmole) of 1-adamantanol II, the mixture is allowed to stand for 1.5 h at 10°C, and 50 ml of water is added. The product is filtered off and washed with water, mp 106-109°C (hexane). Yield, 1.02 g (40%). Found, %: 59.61, H 7.03, N 17.55. $C_{12}H_{16}ClN_3$. Calculated, %: C 60.60, H 6.74, N 17.68.

1-(1-Adamantyl)-1,2,4-triazole (IVf). To a solution of 0.22 g (3.1 mmole) of 1,2,4-triazole If in 7 ml of 85% sulfuric acid is added 0.29 g (1.45 mmole) of 1-adamantanol II, the mixture is kept for 1 h at 15°C, and the reaction mass is diluted with 50 ml of water. The solution obtained is neutralized with sodium hydroxide, the precipitate is filtered off and recrystallized from ethanol, and then from hexane. Yield, 0.46 g (48%), mp 88.5-90.5°C. Found, %: C 71.35, H 9.14, N 20.59. $C_{12}H_{17}N_3$. Calculated, %: C 70.93, H 8.37, N 20.78.

1-(1-Adamantyl)-3-methyl-1,2,4-triazole (IVg). A solution of 0.66 g (8 mmole) of 3(5)-methyl-1,2,4-triazole Ig and 1.52 g (10 mmole) of 1-adamantanol II in 25 ml of 85% sulfuric acid is kept for 1 h at room temperature, 200 ml of water is added, and the mixture is neutralized with sodium hydroxide solution. The precipitate is filtered off, washed with water, and recrystallized twice from heptane with activated charcoal (dissolution temperature not above 50°C). Yield, 0.20 g (12%), mp 52-53°C. Found, %: C 71.97, H 9.85, N 19.44. $C_{13}H_{19}N_3$. Calculated, %: C 71.89, H 8.76, N 19.35.

1-(1-Adamantyl)-3-amino-1,2,4-triazole (IVh). A solution of 0.25 g (3 mmole) of 3(5)-amino-1,2,4-triazole and 0.50 g (3.29 mmole) of 1-adamantanol II in 25 ml of 74% sulfuric acid is kept for 16 h at room temperature and diluted with 250 ml of water. The filtered solution is neutralized with sodium hydroxide to pH 8, and the precipitate is filtered off and washed with water, mp 237-240°C (dec., ethanol). Yield, 0.33 g (48%). Found, %: C 65.71, H 7.94, N 25.84. $C_{12}H_{18}N_4$. Calculated, %: C 66.01, H 8.33, N 25.67.

1,4-Bis(1-adamantyl)-1,2,4-triazolium Nitrate (XIa). To a solution of 0.86 g (12.5 mmole) of 1,2,4-triazole If in 25 ml of 96% sulfuric acid is added 2.75 g (14.0 mmole) of 1-nitroxyadamantane III and the mixture is kept for 3 h at 12-15°C. The reaction mass is diluted with 200 ml of water and extracted with chloroform; the extract is washed with water, dried with magnesium sulfate, then the chloroform is driven off. Yield, 0.30 g (8%), mp 268-270°C (ethanol). Found, %: C 66.61, H 7.51, N 14.07. $C_{22}H_{32}N_4O_3$. Calculated, %: C 66.00, H 8.00, N 14.00.

1,4-Bis(1-adamantyl)-3-methyl-1,2,4-triazolium Bisulfate (XIb). To a solution of 0.92 g (12 mmole) of 3(5)-methyl-1,2,4-triazole Ig in 18 ml of 96% sulfuric acid is added 1.84 g (12 mmole) of 1-adamantanol II, then the mixture is kept for 1 h at 20°C and decanted into 150 ml of ice water. The solution is extracted with chloroform (30 ml $\times$ 3), the extract is dried with magnesium sulfate, and the chloroform is driven off. Recrystallization from acetone yields 0.2 g (8%) of 1-(1-adamantyl)-3-methyl-1,2,4-triazole IVg. Compound XIb (0.15 g), which did not dissolve in acetone, is dissolved in ethanol and precipitated with acetone. Yield, 0.12 g, mp 275-285°C (dec., 2-propanol). Found, %: C 61.24, H 7.72, N 9.19. $C_{23}H_{35}N_3SO_4$. Calculated, %: C 61.47, H 7.80, N 9.35.

1-(1-Adamantyl)-3-methyl-1,2,4-triazole (VIIa). To a solution of 0.64 g (5.0 mmole) of 3-nitro-5-methyl-1,2,4-triazole Id and 0.76 g (5.0 mmole) of 1-adamantanol II in 30 ml of chloroform are added 5 drops of concentrated sulfuric acid, and the mixture is boiled under reflux for 30 h, the condensate being returned into the flask through a drier plug ($MgSO_4$). The reaction mixture is diluted with 20 ml of chloroform and washed with 3% potassium hydroxide solution and water, then the chloroform is evaporated. TLC shows the presence of 1-(1-adamantyl)-3-nitro-5-methyl-1,2,4-triazole IVd (R_f 0.3, faint spot) and compound VIIa (R_f 0.5), as well as adamantanol II (R_f 0.2, development with iodine vapor). Multiple recrystallization from ethanol with activated charcoal gives 0.13 g of product VIIa (yield, 10%), mp 94-97°C. Found, %: C 59.57, H 6.21, N 22.08. $C_{13}H_{18}N_4O_2$. Calculated, %: C 59.51, H 6.93, N 21.36.

1-(1-Adamantyl)-3-bromo-5-nitro-1,2,4-triazole (VIIb). To a solution of 0.48 g (2.5 mmole) of 3-nitro-5-bromo-1,2,4-triazole IVc and 0.38 g (2.5 mmole) of 1-adamantanol II in 30 ml of chloroform is added one drop of concentrated sulfuric acid, and the mixture is boiled under reflux for 6 h (the condensate is returned to the flask through a drier plug of $MgSO_4$). TLC data show that a mixture of substance IVc (R_f 0.3) and substance VIId (R_f 0.7) is obtained. The products are separated chromatographically, and 0.18 g of compound VIIb is obtained (yield, 25%), mp 124-125°C (heptane). Found, %: C 44.23, H 4.37, N 17.43. $C_{12}H_{15}BrN_4O_2$. Calculated, %: C 44.05, H 4.63, N 17.13.

Adamantylation of 3(5)-Nitro-1,2,4-triazole (Ia) in Chloroform. To a solution of 0.91 g (6 mmole) of 1-adamantanol II and 0.70 g (6 mmole) of nitrotriazole Ia in 25 ml of chloroform are added 5 drops of sulfuric acid (0.6% of the weight of

chloroform) and the mixture is boiled for 24 h, the condensate being returned to the flask through an MgSO_4 plug. To the reaction mass is added 15 ml of chloroform, and the mixture is washed with ammonia solution and water and dried over magnesium sulfate. From the mixture obtained, the following compounds are separated chromatographically:

- 1) **1,2-Bis(1-adamantyl)-3-nitro-1,2,4-triazol-3-one (IX)**, 0.12 g (11%), R_f 0.9, mp 163°C (dec.). Found, %: C 65.32, H 7.89, N 12.68. $\text{C}_{22}\text{H}_{30}\text{N}_4\text{O}_3$. Calculated, %: C 64.90, H 7.13, N 12.46.
- 2) **1-(1-Adamantyl)-5-nitro-1,2,4-triazole (VIIc)** 0.16 g (11%), R_f 0.6, mp 109-110°C. Found, %: C 58.41, H 6.76, N 22.85. $\text{C}_{12}\text{H}_{16}\text{N}_4\text{O}_2$. Calculated, %: C 58.06, H 6.45, N 22.58.
- 3) **1,2-Bis(1-adamantyl)-1,2,4-triazol-3-one (VIII)**, 0.28 g (24%), R_f 0.4, mp 290°C. Found, %: C 76.77, H 8.09, N 12.10. $\text{C}_{22}\text{H}_{31}\text{N}_3\text{O}$. Calculated, %: C 74.73, H 8.86, N 11.89.
- 4) **1-(1-Adamantyl)-3-nitro-1,2,4-triazole IVa** [22], 0.12 g (8%), R_f 0.3, mp 137-140°C.

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