SYNTHESIS AND TRANSFORMATIONS OF POLYHEDRAL COMPOUNDS
12.* STEVENS REARRANGEMENT IN THE AZAADAMANTANE SERIES

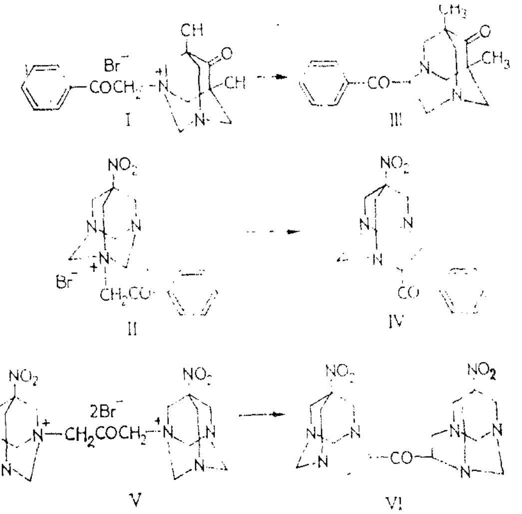
G. G. Minasyan, A. A. Karapetyan, Ts. E. Agandzhanyan
and Yu. T. Struchkov

UDC 547.8.89.853

Some quaternary salts of 1,3-diaza- and 1,3,5-triazaadamantanes undergo the Stevens rearrangement to give derivatives of the corresponding 1,4-diaza- and 1,3,6-triazahomoadamantanes. The structures of the rearrangement products were proved by IR, PMR, and mass spectroscopy and x-ray diffraction analysis (XDA).

We have previously shown that treatment of quaternary salts of 1,3-diaza- and 1,3,5-triazaadamantanes with aqueous alkali at 20°C leads to cleavage of the N$^+$—C bond of the methylenediamino group to give monoalkyl derivatives of, respectively, 3,7-diaza- and 1,3,7-triazabicyclo[3.3.1]nonanes [2, 3].

To ascertain the possibility of the occurrence of the Stevens rearrangement in the azaadamantane series we obtained quaternary salts (I and II, respectively) of 5,7-dimethyl-6-oxo-1,3-diazaadamantane and 7-nitro-1,3,5-triazaadamantane with ω-bromoacetophenone. These quaternary salts undergo the Stevens rearrangement quite smoothly on refluxing in the presence of sodium ethoxide in dry ether or triethylamine in water to give the benzoyl derivatives (III and IV, respectively) of 1,4-diaza- and 1,3,6-triazahomoadamantane. Bisquaternary salt V, obtained by the reaction of 7-nitro-1,3,5-triazaadamantane with 1,3-dibromoacetone in a ratio of 2:1, is also converted to 1,3,6-triazahomoadamantane derivative VI by refluxing in triethylamine—water as a result of the Stevens rearrangement.



The molecular masses of azahomoadamantanes III, IV, and VI, determined by mass spectrometry, correspond to the calculated values. The IR spectra of azahomoadamantanes III and IV contain absorption of a ketone C=O group conjugated with an aromatic ring at 1680-1690 cm^{-1} and of an aromatic ring C=C bond at 1600-1610 cm^{-1}, while absorption of a ketone C=O group at 1700 cm^{-1} is observed in the spectrum of azahomoadamantane VI. In the PMR spectra of III and IV signals of the protons attached to, respectively, the C$_{(2)}$ and C$_{(4)}$ atoms, which are adjacent to the electron-acceptor carbonyl and methyleneamino groups, appear in the form of two doublets in the X part of an

---

*See [1] for Communication 11.

A. L. Mndzhoyan Institute of Fine Organic Chemistry, Academy of Sciences of the Armenian SSR, Yerevan 375014. A. N. Nesmeyanov Institute of Heteroorganic Compounds, Academy of Sciences of the USSR, Moscow 117813. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 5, pp. 669-673, May, 1991. Original article submitted December 22, 1989; revision submitted August 14, 1990.

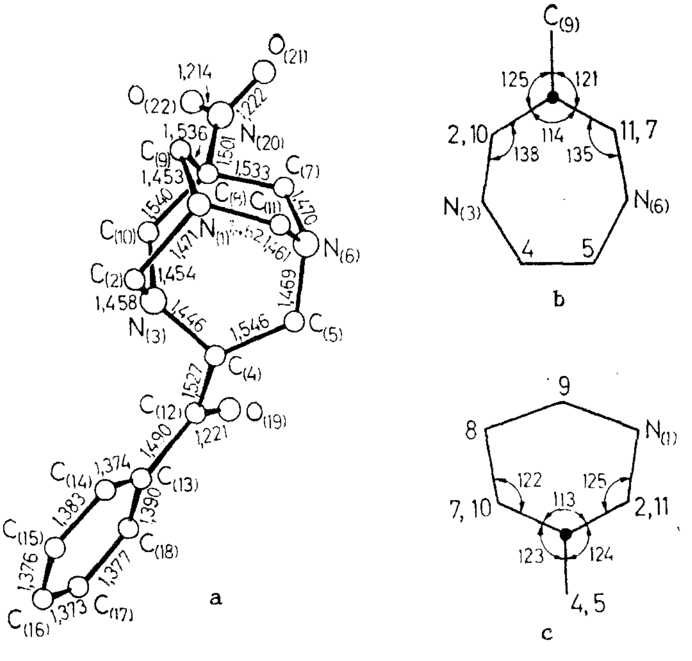


Fig. 1. Structure and schematic projection of the IV molecule: a) structure of the IV molecule with numbering of the nonhydrogen atoms and designation of the bond lengths (σ = 0.004 Å); b) projection along the $N_{(1)}\cdots C_{(8)}$ direction; c) projection along the $N_{(3)}\cdots N_{(6)}$ direction.

TABLE 1. Bond Angles

Angle	ω°	Angle	ω°	Angle	ω°
$C_{(2)}N_{(1)}C_{(9)}$	108,7(2)	$C_{(4)}C_{(5)}N_{(6)}$	116,7(3)	$C_{(10)}C_{(8)}N_{(20)}$	109,0(2)
$C_{(2)}N_{(1)}C_{(11)}$	113,5(2)	$C_{(5)}N_{(6)}C_{(7)}$	114,5(2)	$C_{(8)}C_{(9)}N_{(1)}$	108,1(2)
$C_{(9)}N_{(1)}C_{(11)}$	109,2(2)	$C_{(5)}N_{(6)}C_{(11)}$	116,4(2)	$N_{(3)}C_{(10)}C_{(8)}$	113,6(2)
$N_{(1)}C_{(2)}N_{(3)}$	115,4(2)	$C_{(7)}N_{(6)}C_{(11)}$	111,6(2)	$N_{(1)}C_{(11)}N_{(6)}$	116,5(2)
$C_{(2)}N_{(3)}C_{(4)}$	113,0(2)	$N_{(6)}C_{(7)}C_{(8)}$	111,1(2)	$C_{(4)}C_{(12)}C_{(13)}$	120,6(2)
$C_{(2)}N_{(3)}C_{(10)}$	111,4(2)	$C_{(7)}C_{(8)}C_{(9)}$	106,2(2)	$C_{(4)}C_{(12)}C_{(19)}$	119,8(3)
$C_{(4)}N_{(3)}C_{(10)}$	115,8(2)	$C_{(7)}C_{(8)}C_{(10)}$	113,9(2)	$C_{(13)}C_{(12)}C_{(19)}$	119,6(3)
$N_{(3)}C_{(4)}C_{(5)}$	116,8(2)	$C_{(7)}C_{(8)}N_{(20)}$	107,6(2)	$C_{(8)}N_{(20)}O_{(21)}$	119,2(2)
$N_{(3)}C_{(4)}C_{(12)}$	107,7(2)	$C_{(9)}C_{(8)}C_{(10)}$	110,2(2)	$C_{(8)}N_{(20)}O_{(22)}$	118,1(2)
$C_{(5)}C_{(4)}C_{(12)}$	112,1(2)	$C_{(9)}C_{(8)}N_{(20)}$	109,9(2)	$O_{(21)}N_{(20)}O_{(22)}$	122,7(3)

ABX system with centers at 4.63 and 4.77 ppm (III) and 4.70 and 4.83 ppm (IV). In addition, 1,4-diazahomoadamantane III remains unchanged when it is heated (for 4 h) in acetic anhydride at 90°C, which indicates the absence of a methylenediamino group in its structure and is in agreement with the literature data [4]. The structure of 1,3,6-triazahomoadamantane IV was proved unequivocally and independently by x-ray diffraction analysis (see Fig. 1 and Table 1).

The skeleton of the IV molecule is constructed from two six-membered hexahydropyrimidine and seven-membered perhydrogenated di- and triazepine rings. The latter two heterorings are formed by a $C_{(4)}$—$C_{(5)}$ dimethylene bridge between the $N_{(3)}$ and $N_{(6)}$ atoms of the triazabicyclo[3.3.1]nonane skeleton, which has a chair—chair conformation (see Fig. 1). Both seven-membered heterorings have chair conformations. The four-atom $N_{(3)}$—$N_{(6)}$—$C_{(7)}$—$C_{(10)}$ fragment in the diazepine $N_{(3)}$—$C_{(4)}$—$C_{(5)}$—$N_{(6)}$—$C_{(7)}$—$C_{(8)}$—$C_{(10)}$ ring is actually planar (the maximum individual deviation of these atoms from their average plane does not exceed 0.033 Å), while the deviations of the $C_{(8)}$, $C_{(4)}$, and $C_{(5)}$ atoms from the average plane of this fragment are, respectively, −0.707, 0.997, and 1.152 Å. The four-atom $C_{(2)}$—$N_{(3)}$—$N_{(6)}$—$C_{(11)}$ fragment in the triazepine $N_{(1)}$—$C_{(2)}$—$N_{(3)}$—$C_{(4)}$—$C_{(5)}$—$N_{(6)}$—$C_{(11)}$ ring is actually planar (the maximum individual deviation from the average plane is 0.032 Å), while the $N_{(1)}$, $C_{(4)}$, and $C_{(5)}$ atoms deviate from the average plane of this fragment by −0.656, 1.147, and 0.975 Å, respectively. The di- and triazepine heterorings are fused by the four-atom $N_{(3)}$—$C_{(4)}$—$C_{(5)}$—$N_{(6)}$ fragment, and their fusion is also of the chair—chair type (see Fig. 1, projection along $N_{(3)}\cdots N_{(6)}$).

TABLE 2. Coordinates of the Atoms ($\cdot 10^4$)

Atom	x/a	y/b	z/c	Atom	x/a	y/b	z/c
$N_{(1)}$	1454(4)	3261(1)	3472(3)	$C_{(12)}$	4412(4)	3966(1)	−558(4)
$C_{(2)}$	1312(5)	3698(1)	2700(5)	$C_{(13)}$	3467(4)	4390(1)	−1377(4)
$N_{(3)}$	3201(4)	3830(1)	2095(3)	$C_{(14)}$	1400(5)	4540(1)	−1401(5)
$C_{(4)}$	3057(4)	3663(1)	267(4)	$C_{(15)}$	631(5)	4939(1)	−2162(5)
$C_{(5)}$	3684(5)	3181(1)	146(4)	$C_{(16)}$	1913(6)	5191(1)	−2932(5)
$N_{(6)}$	3627(4)	2903(1)	1652(3)	$C_{(17)}$	3978(6)	5044(1)	−2919(5)
$C_{(7)}$	5614(4)	2926(1)	3245(4)	$C_{(18)}$	4752(5)	4648(1)	−2152(5)
$C_{(8)}$	5489(4)	3313(1)	4481(4)	$O_{(19)}$	6301(3)	3865(1)	−520(3)
$C_{(9)}$	3408(5)	3237(1)	5087(4)	$N_{(20)}$	7552(4)	3302(1)	6119(3)
$C_{(10)}$	5339(4)	3756(1)	3536(4)	$O_{(21)}$	8877(4)	3604(1)	6373(3)
$C_{(11)}$	1589(5)	2917(1)	2177(4)	$O_{(22)}$	7843(4)	2989(1)	7126(4)

The geometrical parameters (the dihedral angles between the average planes, which are presented in Fig. 1, and the average bond angles) show that the triazabicyclo[3.3.1]nonane fragment in the homoazaadamantane skeleton of the IV molecule is somewhat deformed as compared with 1,3,7-triazabicyclo[3.3.1]nonane, 3,7-diazabicyclo[3.3.1]nonane, and 1,3-diazaadamantane derivatives [5-8]. The deformation of the triazabicyclononane skeleton is manifested clearly in the values of the dihedral angles of the planar fragments of the hexahydropyrimidine rings, which are presented in Fig. 1, and in the increased values of the bond angles at the $C_{(2)}$, $C_{(10)}$, $C_{(7)}$, and $C_{(11)}$ atoms (the average value of the bond angles at these atoms is 114.2°). This is evidently due to the presence of a dimethylene "push-apart" bridge between the $N_{(3)}$ and $N_{(6)}$ atoms. The remaining geometrical parameters, particularly the average values of the C—C (1.538 Å) and C—N (1.460 Å) bond lengths and the C—C—C (110.1°), N—C—C (113.3°), N—C—N (115.9°), and C—N—C (112.6°) bond angles, are in good agreement with analogous data for similar structures [5-8] and with the standard values [9].

All of the intermolecular contacts in the structures are close to the sums of the van der Waals radiuses of the corresponding atoms.

EXPERIMENTAL

The IR spectra of suspensions of the compounds in mineral oil were recorded with UR-20 and Specord IR spectrometers. The PMR spectra of solutions in $CDCl_3$ were obtained with a Varian T-60 spectrometer with tetramethylsilane (TMS) as the internal standard. The molecular masses were determined by mass spectrometry with an MKh-1320 spectrometer with direct introduction of the samples into the ion source; the ionizing-electron energy was 60 eV. The course of the reactions and the purity of the substances were monitored by TLC on Silufol UV-254 plates in propanol—water (7:3) (A) and acetone—hexane (1:1) (B) systems with development by iodine vapors.

The results of elementary analysis for C, H, N, and Br were in agreement with the calculated values.

The x-ray diffraction experiments were carried out with a Syntex $P2_1$ automatic diffractometer (Mo K_α emission, graphite monochromator). The monoclinic crystals had the following parameters: $a = 6.292(1)$, $b = 30.779(7)$, $c = 7.667(1)$ Å, $\beta = 108.01(1)°$, $V = 1412.1(4)$ Å^3, $Z = 4$, $d_{calc} = 1.36$ g/cm^3, space group $P2_1/c$. The intensities of 2796 independent reflections over the range $1° \leq \theta$ 26° were measured by $\theta/2\theta$ scanning. In the structural calculations performed with an Eclipse S/200 computer by means of INEXTL programs [10] we used 1509 observed reflections. The structure was decoded by the direct method by means of the MULTAN program and was refined by the method of least squares within the complete-matrix anisotropic approximation for the nonhydrogen atoms. All of the H atoms were localized in differential synthesis of the electron density and were included in the refinement within the isotropic approximation. The final values of the divergence factors were $R = 0.054$ and $R_w = 0.057$ with respect to 1426 reflections with $P^2 \geq 4.5\sigma$. The coordinates of the nonhydrogen atoms are presented in Table 2.

5,7-Dimethyl-6-oxo-3-aza-1-benzoylmethylazoniaadamantane Bromide (I, $C_{18}H_{23}BrN_2O_2$). An 8-g (0.04 mole) sample of ω-bromoacetophenone in 20 ml of dry benzene was added to a solution of 7.2 g (0.04 mole) of 5,7-dimethyl-6-oxo-1,3-diazaadamantane in 150 ml of dry benzene, and the mixture was stirred at 20°C for 2 h. The precipitate was removed by filtration and washed with 50 ml of dry benzene to give 15.1 g (99.3%) of I with mp 203-205°C (dec.) and R_f 0.72 (A).

7-Nitro-3,5-diaza-1-benzoylmethylazoniaadamanatane Bromide (II, $C_{15}H_{19}BrN_4O_3$). A 20-g (0.1 mole) sample of ω-bromoacetophenone in 15 ml of chloroform was added to a refluxing solution of 18.4 g (0.1 mole) of 7-nitro-1,3,5-triazaadamantane in 700 ml of chloroform, and the mixture was refluxed for 3 h. The precipitate was removed by filtration and washed with 50 ml of hot chloroform to give 30 g (78%) of II with mp 212-214°C (dec.) and R_f 0.74 (A).

1,3-Bis(7-nitro-3,5-diaza-1-azoniaadamantanyl)acetone Dibromide (V, $C_{17}H_{28}Br_2N_8O_5$). This compound was obtained in the same way as II from 11.0 g (0.06 mole) of 7-nitro-1,3,5-triazaadamantane and 6.5 g (0.03 mole) of 1,3-dibromoacetone in 450 ml of chloroform after 4 h. The product had mp 187-190°C (dec.) and R_f 0.53 (A). The yield was 17 g (97%).

2-Benzoyl-6,8-dimethyl-7-oxo-1,4-diazatricyclo[4.3.1.1^{4,8}]undecane (III, $C_{18}H_{22}N_2O_2$). A. A 7.6-g (0.02 mole) sample of bromide I was added to a suspension of 7.0 g (0.1 mole) of sodium ethoxide in 100 ml of dry ether, and the mixture was stirred for 1 h at 20°C and for 2 h at 30°C. It was then cooled and filtered, and the precipitate was washed with 50 ml of dry ether. The ether solution was washed with water (two 40-ml portions), dried with magnesium sulfate, and evaporated. The residue was recrystallized from ethanol—water (2:1) to give 2.8 g (47%) of III with mp 103-104°C and R_f 0.6 (B). IR spectrum: 1610 (arom.), 1690 (ketone C=O conjugated with an aromatic ring), 1720 cm^{-1} (ketone C=O). PMR spectrum: 0.77 and 0.87 (3H each, s, s, $2CH_3$), 2.3-3.88 (10H, m, methylene protons), 4.63 and 4.77 (1H, dqd, 2-CH), 7.1-7.65 (3H, m, meta and para aromatic protons), 7.7-8.1 ppm (2H, m, ortho aromatic protons). M^+ 298.

B. A 10-g (0.1 mole) sample of triethylamine was added to a heated (to 30-35°C) solution of 7.0 g (0.018 mole) of bromide I in 100 ml of water, and the mixture was heated for 3 h at 80°C. The triethylamine was removed by distillation, and the liberated oil was extracted with 150 ml of ether. The ether solution was washed with water (two 30-ml portions), dried with magnesium sulfate, and evaporated. The residue was recrystallized from ethanol—water (2:1) to give 3.6 g (65.6%) of III with mp 103-104°C and R_f 0.6 (B).

4-Benzoyl-8-nitro-1,3,6-triazatricyclo[4.3.1.1^{3,8}]undecane (IV, $C_{15}H_{18}N_4O_3$). A. This compound was obtained in the same way as III (method A) from 7.0 g (0.1 mole) of sodium ethoxide and 7.7 g (0.02 mole) of bromide II in 100 ml of dry ether and had mp 177-178°C (ethanol) and R_f 0.67 (A) or 0.35 (B). IR spectrum: 1540 (C—NO_2), 1600 (aromatic C—C), 1680 cm^{-1} (ketone C=O conjugated with an aromatic ring). PMR spectrum: 3.0-4.37 (12H, m, methylene protons), 4.7 and 4.83 (1H, dqd, 4-CH), 7.23-7.67 (3H, m, meta and para aromatic protons), 7.9-8.2 ppm (2H, m, ortho aromatic protons). M^+ 302. The yield was 2.95 g (44.4%).

B. This compound was obtained in the same way as III (method B) from 10.0 g (0.026 mole) of bromide II and 18 g (0.18 mole) of triethylamine in 130 ml of water after 30 min. After cooling of the reaction mixture, the precipitate was removed by filtration, washed with water, and recrystallized from ethanol to give a product with mp 177-178°C and R_f 0.35 (B). The yield was 5.9 g (75%).

Bis(8-nitro-1,3,6-triazatricyclo[4.3.1.1^{3,8}]undec-4-yl) Ketone (VI, $C_{17}H_{26}N_8O_5$). This compound was obtained in the same way as IV (method B) by refluxing 15.0 g (0.026 mole) of bromide V in a mixture of 10.0 g (0.1 mole) of triethylamine and 50 ml of water for 3 h. The product had mp 277-279°C (DMF, dec.) and R_f 0.4 (A). IR spectrum: 1545 (C—NO_2), 1700 cm^{-1} (ketone C=O). M^+ 422. The yield was 6.8 g (62.7%).

LITERATURE CITED

1. G. G. Minasyan, G. S. Saakyan, Ts. E. Agadzhanyan, A. A. Chachoyan, and B. T. Garibdzhanyan, *Armyansk. Khim. Zh.*, **43**, 107 (1990).
2. G. G. Minasyan, M. B. Mkrtchyan, and Ts. E. Agadzhanyan, *Armyansk. Khim. Zh.*, **39**, 44 (1986).
3. Ts. E. Agadzhanyan, G. G. Minasyan, and R. A. Movsesyan, *Armyansk. Khim. Zh.*, **37**, 530 (1984).
4. T. Sasaki, Sh. Eguchi, T. Kiriyama, and Y. Sakito, *J. Org. Chem.*, **38**, 1648 (1973).
5. A. A. Karapetyan, G. G. Minasyan, Ts. E. Agadzhanyan, and Yu. T. Struchkov, *Armyansk. Khim. Zh.*, **39**, 108 (1986).
6. N. S. Zefirov, V. A. Palyulin, O. I. Levina, K. A. Potekhin, E. N. Kurkutova, and Yu. T. Struchkov, *Vestnik Moskovsk. Univ., Ser. 2, Khim.*, **28**, 276 (1987).
7. H. Quast, B. Muller, E. Peters, K. Peters, and H. G. von Schnering, *Chem. Ber.*, **115**, 3631 (1982).
8. O. L. Levina, E. N. Kurkutova, K. A. Potekhin, Yu. T. Struchkov, V. A. Palyulin, and N. S. Zefirov, *Cryst. Struct. Commun.*, **11**, 1915 (1982).
9. F. H. Allen, O. Kennard, D. G. Watson, L. Brammer, A. G. Orpen, and R. Taylor, *J. Chem. Soc., Perkin Trans. 2*, No. 12, S1 (1987).
10. R. G. Gerr, A. I. Yanovskii, and Yu. T. Struchkov, *Kristallografiya*, **28**, 1029 (1983).