Synthesis of pyrimidinophanes containing nitrogen atoms in polymethylene bridges

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The reactions of 1,3-bis(ω-bromobutyl- or -pentyl)-6-methyluracil with 1,3-bis(ω-ethylaminobutyl- or -pentyl)-6-methyluracil afforded pyrimidinophanes containing N atoms in bridging polymethylene chains. Individual geometric isomers of pyrimidinophanes were isolated. The structure of one of these isomers was established by X-ray diffraction analysis. Quaternization of the bridging N atoms with *o*-nitrobenzyl bromide gave rise to water-soluble pyrimidinophanes.

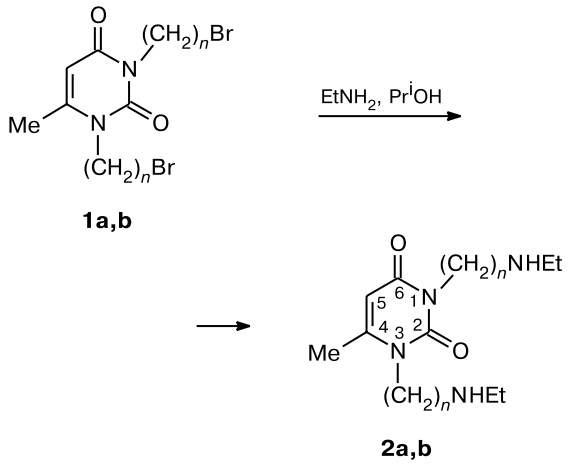
Key words: macrocyclic compounds, pyrimidinophanes, uracilophanes, quaternization.

Macrocyclic compounds containing the purine and pyrimidine bases are of interest as models for studying interactions between nucleotide fragments of nucleic acids and also as potential guest—host complexation agents. Purinophanes of different types have been studied in sufficient detail,[1] whereas first syntheses of pyrimidinophanes have been carried out only in recent years.[2—10] A direct procedure has been developed for the synthesis of pyrimidinophanes consisting of two 2,4-dioxo-1,2,3,4-tetrahydropyrimidine (uracil) fragments linked by polyethylene bridges through the N(1) and N(3) atoms of the pyrimidine rings.[2—4] This method is based on the reactions of uracils with dihaloalkanes in DMF in the presence of NaH. The pyrimidinophanes thus prepared were separated into individual geometric isomers[2] (whose existence has been predicted earlier[11—13]), which differ in the mutual arrangement of the carbonyl and methyl groups at different pyrimidine rings. It is impossible to assign particular structures to these isomeric compounds because of the lack of X-ray diffraction data.

Almost all known pyrimidinophanes are insoluble in water, which hinders their study. Water-soluble [16-pyrimidinium crown-4]$^{4+}$ and [24-pyrimidinium crown-6]$^{6+}$ chlorides were described only in the study.[14] The latter compounds were prepared by the reactions of nickel or zinc acetate with thiamine hydrochloride. With the aim of preparing water-soluble pyrimidinophanes and studying their complexation properties and biological activities, we synthesized macrocycles containing N atoms in the linking bridges.

The reactions of 1,3-bis(4-bromobutyl)-6-methyluracil (**1a**) and 1,3-bis(5-bromopentyl)-6-methyluracil (**1b**) with ethylamine afforded 1,3-bis(4-ethylaminobutyl)-6-methyluracil (**2a**) and 1,3-bis(5-ethylaminopentyl)-6-methyluracil (**2b**), respectively, as oils (Scheme 1).

Scheme 1



n = 4 (**a**), 5 (**b**)

The IR spectra of compounds **2a** and **2b** have bands in the region of 3140—3410 cm^{-1} (ν(NH)). The positions and structures of signals in the ^{1}H NMR spectrum of **2a** in $CDCl_3$ (5 mmol L^{-1}) differ from those in the spectrum

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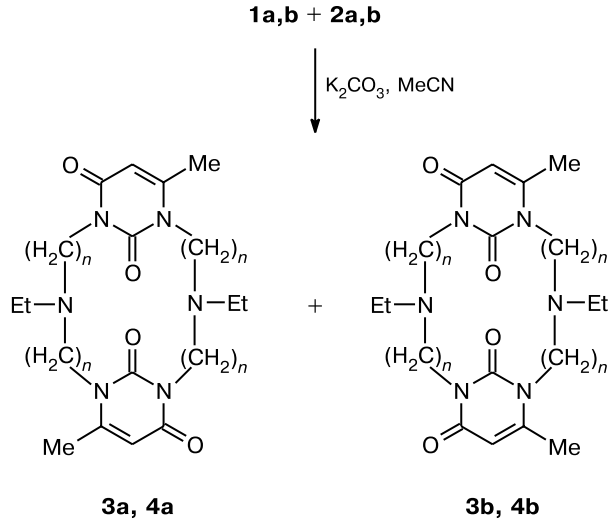
of **2b**. Thus, the spectrum of **2b** has a signal of NH (δ 2.81) at higher field (by 2 ppm) compared to that in the spectrum of **2a**. In addition, signals of one of the methylene groups at the nitrogen atom in the alkyl chain of **2a** are observed as an individual multiplet (δ 3.15), whereas the spectrum of **2b** shows signals of protons of all methylene groups at the nitrogen atoms in the alkyl chain in a single region (δ 2.74—2.64).

The reactions of compounds **1a** and **1b** with **2a** and **2b**, respectively, produced isomeric pyrimidinophanes **3a,b** and **4a,b** (Scheme 2). We succeeded in isolating these isomers by repeated column chromatography on silica gel (AcOEt—Et_2NH as the eluent).

Scheme 2



n = 4 (**3**), 5 (**4**)

One of the isomers of pyrimidinophane, which was synthesized from compounds **1a** and **2a** and isolated from first fractions of the eluate, was studied by X-ray diffraction analysis (Fig. 1), which demonstrated that this isomer has structure **3a**. In the crystal, molecules **3a** occupy special positions. These molecules are centrosymmetrical macrocycles containing the extended alkyl chains and pyrimidine rings, which are parallel to each other. In the crystal, the molecules are linked by intermolecular C—H...O and π...π contacts, which exert a substantial effect on the molecular packing. The results of X-ray diffraction analysis of this compound will be considered in more detail elsewhere.

On the assumption that the order of elution of pyrimidinophane **3** on a chromatographic column is the same as that of **4**, formulas **4a** and **4b** can be arbitrarily assigned to the isomers of pyrimidinophane isolated from first fractions of the eluate and subsequent fractions, respectively.

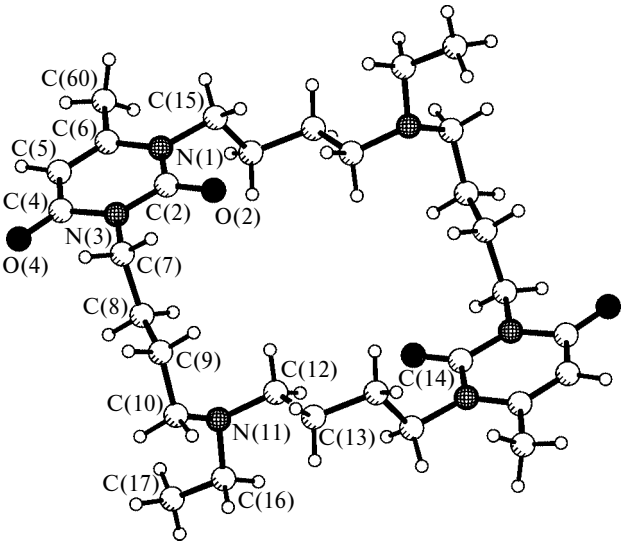


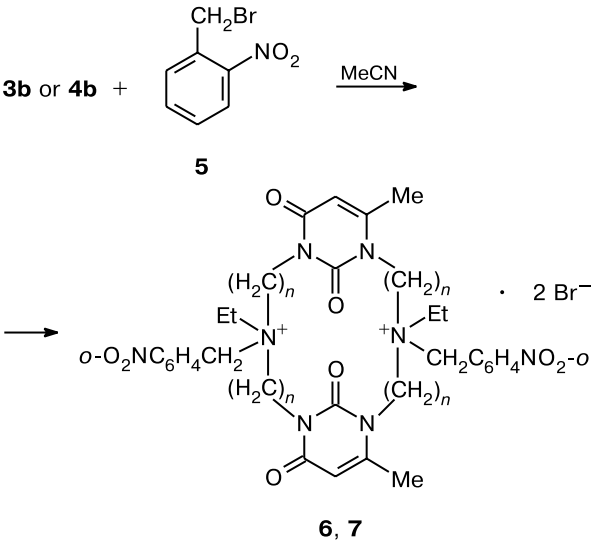
Fig. 1. Molecular structure of compound **3a** in the crystal.

In the mass spectra (EI) of pyrimidinophanes **3a,b** and **4a,b**, the experimental values of *m/z* for $[M]^+$ agree well with the calculated values, although the most intense peaks correspond to products of elimination of the methyl or ethyl group from the molecular ion.

We succeeded in preparing water-soluble pyrimidinophanes **6** and **7** by quaternization of the bridging nitrogen atoms in compounds **3b** and **4b**, respectively, with *o*-nitrobenzyl bromide (**5**) (Scheme 3).

Crystalline compounds **6** and **7** decomposed at temperatures above 130 and 60 °C, respectively. Upon dissolution in water, compounds **6** and **7** gave viscous solutions, which hindered the withdrawal of aliquots.

Scheme 3



n = 4 (**6**), 5 (**7**)

In the IR spectra of compounds **6** and **7**, the ν(NCH_2) band at 2800 cm^{-1} is absent, which is characteristic of quaternized tertiary amines.[15] In the ^1H NMR spectra (D_2O, CD_3CN) of compounds **6** and **7**, the signals of the protons at the quaternized N atoms are substantially shifted downfield compared to those in the ^1H NMR spectra of the starting pyrimidinophanes.

To summarize, the individual geometric isomers of pyrimidinophanes were synthesized by the reactions of 1,3-bis(ω-bromobutyl- or -pentyl)-6-methyluracil with 1,3-bis(ω-ethylaminobutyl- or -pentyl)-6-methyluracil and their structures were established by X-ray diffraction analysis. Quaternization of the N atoms in the polymethylene bridges of these compounds yielded water-soluble pyrimidinophanes.

Experimental

The IR spectra (in KBr) were recorded on a Vector 22 Fourier spectrometer (Bruker) under standard conditions. The UV spectra were measured on a Specord UV-Vis spectrophotometer. The ^1H NMR spectra were recorded on Bruker WM-250 (250.13 MHz) and MSL-400 (400.13 MHz) spectrometers with Me_4Si as the internal standard. The assignment of resonances was made based on their multiplet structures and integral intensities and also by comparing with the spectra of the model compounds. The mass spectra (EI) were obtained on a Finnigan MAT-212 mass spectrometer (resolution was 1000; data were processed using the MSS MASPEC II data system;[32] direct inlet of the sample into the ion source, programming of the temperature from 20 to 300 °C, energy of ionizing electrons was 70 eV, electron emission current was 1.0 mA). The melting points were measured on a Boetius hot-stage apparatus and were not corrected. Chromatography was performed in a thin layer on Silufol-254 plates; visualization was carried out with UV light.

All solvents were dried according to standard procedures.

1,3-Bis(4-bromobutyl)-6-methyluracil (1a) and 1,3-bis(5-bromopentyl)-6-methyluracil (1b) were prepared according to a known procedure.[16]

1,3-Bis(4-ethylaminobutyl)-6-methyluracil (2a). Dibromide **1a** (5 g, 12.6 mmol) was added to a 20% $EtNH_2$ solution in Pr^iOH (100 mL). The reaction mixture was kept at ~20 °C for 5 days and then concentrated *in vacuo*. A solution of MeONa, which was prepared from Na (0.58 g, 25.2 mmol) in MeOH (30 mL), was added to the residue. The solvent was evaporated *in vacuo* and the reaction product was extracted with Et_2O (2×50 mL). The ether was distilled off to obtain compound **2a** in a yield of 4 g (93%), R_f 0.49 (5 : 1 : 1 AcOEt—MeOH—Et_2NH as the eluent), oil. Found (%): C, 63.12; H, 9.96; N, 17.36. $C_{17}H_{32}N_4O_4$. Calculated (%): C, 62.96; H, 9.88; N, 17.28. ^1H NMR ($CDCl_3$), δ:* 5.57 (s, 1 H, C(5)H); 4.78 (br.s, 2 H, 2NH); 3.95 and 3.86 (both m, 2 H each, $2NCH_2$); 3.15 (m, 2 H, $NHC\underline{H}_2$); 2.74 (m, 6 H, $3NHC\underline{H}_2$); 2.26 (s, 3 H, $C(6)_{pyr}Me$); 1.70—1.58 (m, 8 H, $4CH_2$); 1.24 and 1.23 (both t, 3 H each, $2NHCH_2C\underline{H}_3$, J = 7 Hz).

1,3-Bis(5-ethylaminopentyl)-6-methyluracil (2b) was prepared analogously from dibromide **1b** (5.7 g, 13.4 mmol) in a yield of 3.85 g (82%). R_f 0.37 (10 : 2 : 1 AcOEt—MeOH—Et_2NH as the eluent), oil. Found (%): C, 64.84; H, 10.36; N, 16.22. $C_{19}H_{36}N_4O_2$. Calculated (%): C, 64.77; H, 10.23; N, 15.91. ^1H NMR ($CDCl_3$), δ:* 5.54 (s, 1 H, C(5)H); 3.90 (m, 2 H, NCH_2, J = 14.4 Hz); 3.79 (m, 2 H, $N_{pyr}CH_2$, J = 15.2 Hz); 2.81 (br.s, 2 H, 2NH); 2.71 (q, 4 H, $2NHC\underline{H}_2CH_3$); 2.66 (m, 4 H, $2NHC\underline{H}_2$); 2.23 (s, 3 H, $C(6)_{pyr}Me$); 1.62 (m, 8 H, $4CH_2$); 1.40 (m, 4 H, $2CH_2$); 1.17 and 1.16 (both t, 3 H each, $2NHCH_2C\underline{H}_3$, J = 7 Hz).

6,20-Diethyl-12,28-dimethyl-1,6,11,15,20,25-hexaazatricyclo[23.3.1.1^{11,15}]triaconta-12,27-diene-14,26,29,30-tetraone (3a) and 6,20-diethyl-14,28-dimethyl-1,6,11,15,20,25-hexaazatricyclo[23.3.1.1^{11,15}]triaconta-13,27-diene-12,26,29,30-tetraone (3b). Potassium carbonate (4.5 g, 32.6 mmol) was added to a solution of dibromide **1a** (4.65 g, 11.7 mmol) and diamine **2a** (3.7 g, 11.4 mmol) in MeCN (100 mL). The reaction mixture was stirred at 40—60 °C for 7 h and then at the boiling temperature of the solvent for 7 h. The precipitate that formed was filtered off. The solution was concentrated to 10—20 mL and transferred to a column with SiO_2. The column was successively washed with Et_2O, AcOEt, and a 10 : 1 AcOEt—Et_2NH mixture. From the AcOEt—Et_2NH fractions, crystalline pyrimidinophane **3a** was obtained in a yield of 0.3 g (5%), R_f 0.28 (10 : 10 : 1 Et_2O—AcOEt—Et_2NH as the eluent), m.p. 130—130.5 °C (MeCN). Found (%): C, 64.56; H, 9.10; N, 15.10. $C_{30}H_{50}N_6O_4$. Calculated (%): C, 64.48; H, 8.95; N, 15.04. Found: m/z 558.391 $[M]^+$. $C_{30}H_{50}N_6O_4$. Calculated: M = 558.3893. UV ($CHCl_3$), λ_{max}/nm (log ε): 268 (4.31). IR (KBr), ν/cm^{-1}: 2957, 2925, 2866, 1468, 1452, 1432, 1400, 1384, 1363, 731 (Me, CH_2), 2809 (CH_2N), 1700, 1667 (CO, uracil fragment). ^1H NMR ($CDCl_3$), δ: 5.54 (s, 2 H, $2C(5)_{pyr}H$); 3.94 (m, 4 H, $2N_{pyr}CH_2$, J = 13.6 Hz); 3.81 (m, 4 H, $2N_{pyr}CH_2$, J = 15.0 Hz); 2.47 (q, 4 H, $2NC\underline{H}_2Me$); 2.42 (m, 8 H, $4NC\underline{H}_2$); 2.24 (s, 6 H, $2C(6)_{pyr}Me$); 1.65 and 1.47 (both m, 8 H each, $8CH_2$); 0.98 (t, 6 H, $2NCH_2C\underline{H}_3$, J = 7 Hz). MS, m/z (I_{rel} (%)): 559 $[M + 1]^+$ (14), 558 $[M]^+$ (45), 544 (26), 543 $[M - 15]^+$ (76), 529 $[M - 29]^+$ (100), 335 (17), 278 (12), 238 (10), 181 (11), 175 (22), 138 (8), 127 (9), 124 (5).

Pyrimidinophane **3b** was obtained as oil from subsequent fractions in a yield of 0.6 g (9%), R_f 0.18 (10 : 10 : 1 Et_2O—AcOEt—Et_2NH as the eluent). Found (%): C, 64.44; H, 8.90; N, 15.18. $C_{30}H_{50}N_6O_4$. Calculated (%): C, 64.48; H, 8.95; N, 15.04. Found: m/z 558.391 $[M]^+$. $C_{30}H_{50}N_6O_4$. Calculated: M = 558.3893. UV ($CHCl_3$), λ_{max}/nm (log ε): 268 (4.12). IR (KBr), ν/cm^{-1}: 2962, sh 2933, 2868, 1470, 1458, 1432, 1402, 1371, sh 1350, 733 (Me, CH_2), 2806 (CH_2CN), 1698, 1656 (uracil fragment). ^1H NMR ($CDCl_3$), δ: 5.56 (s, 2 H, $2C(5)_{pyr}H$); 3.94 (m, 4 H, $2N_{pyr}CH_2$, J = 13.6 Hz); 3.84 (m, 4 H, $2N_{pyr}CH_2$, J = 14.1 Hz); 2.46 (q, 4 H, $2NCH_2$); 2.43 (m, 8 H, $4NCH_2$); 2.24 (s, 6 H, $2C(6)_{pyr}Me$); 1.65 and 1.48 (both m, 8 H each, $8CH_2$); 1.00 (t, 6 H, $2NCH_2C\underline{H}_3$, J = 6.5 Hz). MS, m/z (I_{rel} (%)): 559 $[M + 1]^+$ (10), 558 $[M]^+$ (29), 544 (34), 543 $[M - 15]^+$ (100), 529 $[M - 29]^+$ (97), 335 (18), 278 (13), 238 (26), 181 (23), 175 (36), 138 (19), 127 (16), 124 (11).

* For multiplets, either the ranges of chemical shifts or chemical shifts of their centers are given.

* For the $N_{pyr}CH_2$ terminal groups, the sums of the vicinal coupling constants ($^3J_{A,X} + {}^3J_{A,X'}$) of the AA´ fragment of the AA´XX´ system are given.

7,23-Diethyl-14,32-dimethyl-1,7,13,17,23,29-hexaazatricyclo[27.3.1.1^{13,17}]tetratriaconta-14,31-diene-16,30,33,34-tetraone (4a) and 7,23-diethyl-16,32-dimethyl-1,7,13,17,23,29-hexaazatricyclo[23.3.1.1^{13,17}]tetratriaconta-15,31-diene-14,30,33,34-tetraone (4b) were prepared analogously from dibromide **1b** (4.55 g, 10.7 mmol), diamine **2b** (3.5 g, 10.5 mmol), and K_2CO_3 (4.35 g, 31.5 mmol) in MeCN (200 mL). Crystalline compound **4a** was isolated from the AcOEt—Et_2NH fractions (10 : 1) in a yield of 0.29 g (4%), R_f 0.65 (10 : 10 : 1 Et_2O—AcOEt—Et_2NH as the eluent), m.p. 165—167.5 °C. Found (%): C, 66.31; H, 9.38; N, 13.58. $C_{34}H_{58}N_6O_4$. Calculated (%): C, 66.40; H, 9.44; N, 13.67. Found: *m/z* 614.451 $[M]^+$. $C_{34}H_{58}N_6O_4$. Calculated: M = 614.4520. UV ($CHCl_3$), λ_{max}/nm (log ε): 268 (4.34). IR (KBr), ν/cm^{-1}: 2937, 2905, 2860, 1471, 1454, 1434, 1403, 1365, 732 (CH_3, CH_2), 2800 (CH_2N), 1700, 1651 (CO, uracil fragment). ^{1}H NMR ($CDCl_3$), δ: 5.57 (s, 2 H, 2C(5)$_{pyr}$H); 3.90 (m, 4 H, 2N$_{pyr}$C$\underline{H}_2$, J = 15.0 Hz); 3.78 (m, 4 H, 2N$_{pyr}$C$\underline{H}_2$, J = 15.4 Hz); 2.49 (q, 4 H, 2NC$\underline{H}_2$Me); 2.40 (m, 8 H, 4NC$\underline{H}_2$); 2.24 (s, 6 H, 2C(6)$_{pyr}$Me); 1.65, 1.48, and 1.33 (all m, 8 H each, 12C$\underline{H}_2$); 1.01 (t, 6 H, 2NCH$_2$C$\underline{H}_3$, J = 7.2 Hz). ^{1}H NMR (acetone-d_6), δ: 5.52 (s, 1 H, C(5)$_{pyr}$H); 3.87 (m, 8 H, 4N$_{pyr}$C$\underline{H}_2$, J = 14.7); 3.00 (m, 4 H, 2NC$\underline{H}_2$); 2.57 (m, 8 H, 4NC$\underline{H}_2$); 2.32 (s, 6 H, 2C(6)$_{pyr}$Me); 1.71—1.62 (m, 16 H, 8C$\underline{H}_2$); 1.41 and 1.35 (both m, 4 H each, 4C$\underline{H}_2$); 1.09 (m, 6 H, 2NCH$_2$C$\underline{H}_3$). MS, *m/z* (I_{rel} (%)): 615 $[M + 1]^+$ (30), 614 $[M]^+$ (75), 600 (15), 599 $[M - 15]^+$ (48), 585 $[M - 29]^+$ (100), 571 (20), 307 (20), 189 (38).

Crystalline compound **4b** was isolated from subsequent fractions in a yield of 0.40 g (6%), R_f 0.55 (10 : 10 : 1 Et_2O—AcOEt—Et_2NH as the eluent), m.p. 133—134 °C. Found (%): C, 66.49; H, 9.41; N, 13.70. $C_{34}H_{58}N_6O_4$. Calculated (%): C, 66.40; H, 9.44; N, 13.67. Found: *m/z* 614.451 $[M]^+$. $C_{34}H_{58}N_6O_4$. Calculated: M = 614.4520. UV ($CHCl_3$), λ_{max}/nm (log ε): 269 (4.35). IR (KBr), ν/cm^{-1}: 2937, 2905, 2860, 1471, 1454, 1434, 1403, 1365, 732 (Me, CH_2), 2800 (CH_2CN), 1700, 1657 (uracil fragment). ^{1}H NMR ($CDCl_3$), δ: 5.57 (s, 2 H, 2C(5)$_{pyr}$H); 3.90 (m, 4 H, 2N$_{pyr}$C$\underline{H}_2$, J = 14.9 Hz); 3.79 (m, 4 H, 2N$_{pyr}$C$\underline{H}_2$, J = 15.4 Hz); 2.50 and 2.49 (both q, 2 H each, 2NC$\underline{H}_2$Me); 2.40 (m, 8 H, 4NC$\underline{H}_2$); 2.24 (s, 6 H, 2C(6)$_{pyr}$Me); 1.65, 1.48, and 1.37 (all m, 8 H each, 12C$\underline{H}_2$); 1.01 (t, 6 H, 2NCH$_2$C$\underline{H}_3$, J = 7.0 Hz). ^{1}H NMR (acetone-d_6), δ: 5.54 (s, 1 H, C(5)$_{pyr}$H); 3.89 (m, 8 H, 4N$_{pyr}$C$\underline{H}_2$, J = 14.3); 3.00—2.83 (m, 12 H, 6NC$\underline{H}_2$); 2.32 (s, 6 H, 2C(6)$_{pyr}$Me); 1.72—1.65 (m, 16 H, 8C$\underline{H}_2$); 1.44 and 1.37 (both m, 4 H each, 4C$\underline{H}_2$); 1.22 (m, 6 H, 2NCH$_2$C$\underline{H}_3$). MS, *m/z* (I_{rel} (%)): 615 $[M + 1]^+$ (15), 614 $[M]^+$ (49), 600 (21), 599 $[M - 15]^+$ (61), 585 $[M - 29]^+$ (100), 571 (20), 363 (24), 307 (19), 189 (61).

[6,20-Diethyl-14,28-dimethyl-6,20-di-(*o*-nitrobenzyl)-12,26,29,30-tetraoxo-1,11,15,25-tetraaza-6,20-diazoniatricyclo[23.3.1.1^{11,15}]triaconta-13,27-diene] dibromide (6). A solution of pyrimidinophane **3b** (0.20 g, 0.36 mmol) and bromide **5** (0.18 g, 0.83 mmol) in MeCN (30 mL) was refluxed for 3 h. The solvent was distilled off. The residue was thoroughly triturated in Et_2O (50 mL) and then filtered. Compound **6** was prepared in a yield of 0.27 g (76%), it decomposed at a temperature >130 °C. Found (%): C, 53.53; H, 6.04; N, 11.10; Br, 15.95. $C_{44}H_{62}Br_2N_8O_8$. Calculated (%); C, 53.33; H, 6.43; N, 11.42; Br, 15.49. ^{1}H NMR (CD_3CN), δ: 8.08 (d, 2 H, 2CH$_{arom}$, J = 7.6 Hz); 7.82—7.76 (m, 6 H, 6CH$_{arom}$); 5.56 (s, 1 H, 2C(5)$_{pyr}$H); 4.92 and 4.85 (both s, 2 H each, 2Bn); 3.85 (m, 8 H, 4N$_{pyr}$C$\underline{H}_2$); 3.33 (m, 4H, 2N$^+$C$\underline{H}_2$); 3.31—3.26 (m, 8 H, 4N$^+$C$\underline{H}_2$); 2.26 (s, 6 H, 2C(6)$_{pyr}$Me); 1.65 (m, 16 H, 8C$\underline{H}_2$); 1.33 (t, 6 H, 2N$^+$CH$_2$C$\underline{H}_3$, J = 6.7 Hz).

[7,23-Diethyl-16,32-dimethyl-7,23-di-(*o*-nitrobenzyl)-14,30,33,34-tetraoxo-1,13,17,29-tetraaza-7,23-diazoniatricyclo[27.3.1.1^{13,17}]tetratriaconta-15,31-diene] dibromide (7) was prepared analogously from a solution of pyrimidinophane **4b** (0.20 g, 0.33 mmol) and bromide **5** (0.16 g, 0.74 mmol) in MeCN (30 mL) in a yield of 0.30 g (91%). Compound **7** decomposed at a temperature >60 °C. Found (%): C, 54.88; H, 6.87; N, 10.43; Br, 15.01. $C_{48}H_{70}Br_2N_8O_8$. Calculated (%): C, 55.07; H, 6.69; N, 10.09; Br, 14.64. IR (KBr), ν/cm^{-1}: 2953, 2865, 2468, 1470, 1452, 1432, 1404, 725 (CH_3, CH_2), 1694, 1653 (CO, uracil fragment), 1528, 1351 (NO_2). ^{1}H NMR (CD_3CN), δ: 8.06 (d, 2 H, 2CH$_{Ar}$, J = 8 Hz); 7.86—7.78 (m, 6 H, 6CH$_{arom}$); 5.53 (s, 1 H, 2C(5)$_{pyr}$H); 4.94 and 4.89 (both s, 2 H each, 2Bn); 3.84 (m, 4 H, 2N$_{pyr}$C$\underline{H}_2$, J = 13.7 Hz); 3.81 (m, 4 H, 2N$_{pyr}$C$\underline{H}_2$, J = 14.4 Hz); 3.25 (m, 4 H, 2N$^+$C$\underline{H}_2$CH$_3$, J = 7); 3.18 (m, 8 H, 4N$^+$C$\underline{H}_2$); 2.25 (s, 6 H, 2C(6)$_{pyr}$Me); 1.76 and 1.63 (both m, 8 H each, 8C$\underline{H}_2$); 1.32 (m, 14 H, 4C$\underline{H}_2$, 2N$^+$CH$_2$C$\underline{H}_3$).

Single-crystal X-ray diffraction analysis of 3a. The study was carried out at the Department of X-ray Diffraction Studies of the Center of Collaborative Use of the Russian Foundation for Basic Research (Project No. 00-03-40133) based on the Laboratory of Diffraction Methods of the A. E. Arbuzov Institute of Organic and Physical Chemistry of the Kazan Research Center of the Russian Academy of Sciences.

Crystals of **3a** ($C_{30}H_{50}N_6O_4$) are monoclinic, space group $P2_1/n$ (molecule occupies a special position in the center of symmetry); at 20 °C, a = 7.675(5), b = 23.95(2), c = 8.538(4) Å, β = 99.81(5)°, V = 1546(2) Å^3, Z = 2, μ = 6.1 cm^{-1}, d_{calc} = 1.20 g cm^{-3}. The unit cell parameters and intensities of 3487 reflections, of which 1371 reflections are with $I \geq 3\sigma$, were measured on an automated CAD-4 diffractometer (NONIUS B. V.) (20 °C, graphite monochromator, Cu-Kα radiation, 2θ/ω scanning technique, $\theta_{max} \leq 75°$). The intensities of three check reflections showed no decrease in the course of data collection and, therefore, the absorption corrections were not applied.

The structure was solved by direct methods using the SIR program[17] and refined with anisotropic thermal parameters for nonhydrogen atoms. The positions of the hydrogen atoms were revealed from difference Fourier syntheses and refined with fixed positional and isotropic temperature parameters. The final reliability factors are as follows: R = 0.047, R_w = 0.047 for 991 independent reflections with $I \geq 3\sigma$. All calculations were carried out with the use of the MolEN program package.[18] Intermolecular interactions were analyzed and the molecule was drawn using the PLATON program.[19]

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