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Selective Reductive Dimerization of Homocubane Series Oximes

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Abstract—The mixture of di- and monoethylene ketals obtained by the reaction of 1,9-dibromopentacyclo[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]-undeca-8,11-dione followed by hydrolysis and ring contraction by Faworsky method was converted into a mixture of ethylene ketals of 7-bromopentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one-4- and 5-bromopentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one-8-carboxylic acid where the carboxy group was replaced by bromine along the procedure of Hunsdiecker–Borodine–Cristol. 6-Ethylene ketal of the pentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one obtained by the debromination of ethylene ketals of 4,7- and 5,8-dibromopentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one was hydrolyzed to ketone whose oxime was selectively reduced on a platinum catalyst into the di-6-pentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decylamine. The reaction of reductive dimerization was also characteristic of pentacyclo[4.3.0.0^{2,5}.0^{3,8}.0^{4,7}]-nonan-9-one and pentacyclo[6.3.0.0^{2,6}.0^{3,10}.0^{5,9}]undecan-4-one oximes, whereas the composition of the reduction products of pentacyclo[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]undecan-8-one oxime depended on the amount of the catalyst.

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The potential for medicine of framework polycylic amines was discovered by revealing the antiviral activity of 1-aminoadamantane (amantadine). Nowadays diverse amines of the adamantsne series {amantadine, rimantadine [1-(1-aminoethyl)adamantane], memantine (1-amino-3,5-dimethyladamantane), adapromine (α-ethyl-1-adamantylmethylamine)} are commercial drugs widely ued in the prophylactics and treatment of various viral diseases like grippe A, hepatitis C, herpes, and also of Alzheimer and Parkinson illness [1–3].

The constantly growing interest in homocubanes, moderately strained framework hydrocarbons, is due first of all to their availability and the possibility of further functionalization, and also to the topological variety of the potential physiologically active substances prepared therefrom. Especial interest is attracted by the derivatives of the most accessible pentacyclo-[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]undecane (C_S-trishomocubane) and $C_{11}H_{14}$-stable isomer of pentacyclo[6.3.0.0^{2,6}.0^{3,10}.0^{5,9}]undecane (D_3-trishomocubane). The anticataleptic [4] and antiviral [5] activity of D_3-trishomocubyl-4-amines was lately investigated. The anticataleptic activity was also found in C_S-trishomocubyl-8-amines but their use is prevented by the high toxicity [6].

Since the moment of the discovery of the activity of NGP1-01 (8-benzylamino-8,11-oxapentacyclo[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]-undecane) as calcium antagonist [7] the biological activity of the aminopentacycloundecanes started to be more thoroughly investigated. The high efficiency was proved of NGP1-01 and a series of substituted pentacycloundecylamines as antagonists of the receptor of N-methyl-D-aspartate (NMDA) [8], and also the possibility was found to use NGP1-01 as a neuroprotector at the focal ischemia [9]. It was also proved that the efficiency of the pentacycloundecylamines as antagonists of the NMDA-receptors depended directly on the volume and the character of the framework substituent and also on the extent of its distance from the other functional groups (e.g., from the benzyl in the case of NGP1-01) [8].

Although the studies on the biological activity of the homocubylamines are continuously growing the set of the available structures is very limited. This stimulates

the search for simple and convenient methods of preparation of new derivatives, especially of secondary amines structurally similar to the NGP1-01 drug.

The traditional procedure for the preparation of the secondary amines is the ammonolysis of the appropriate haloderivatives or alcohols, but the selectivity of these reactions is commonly poor. Another way to the framework dialkylamines is the reduction of amides obtained from the framework amines and the corresponding framework carboxylic acids [10]. However this method affords only dialkylamines where the framework is separated from the amino group by one or two CH_2 units.

By the Leuckart reaction from the adamantanone with 1- or 2-aminoadamantane in severe conditions [11, 12] the corresponding diadamantylamines were obtained. No published data exist on the synthesis of any other diframework amines.

We report here on a simple and selective procedure for the synthesis of di-6-pentacyclo-[5.3.0.$0^{2,5}$.$0^{3,9}$.$0^{4,8}$] decylamine and some its homologs where the identical framework fragments are directly bound to the nitrogen atom.

We selected as the initial compound for the synthesis of di-6-pentacyclo[5.3.0.$0^{2,5}$.$0^{3,9}$.$0^{4,8}$]decylamine (**XII**) 1,9-dibromopentacyclo[5.4.0.0^{2,6}.$0^{3,10}$.$0^{5,9}$]undeca-8,11-dione (**I**) prepared along the described four-stage procedure [13] from hydroquinone and cyclopentadiene.

The boiling of compound **I** with excess ethylene glycol in benzene afforded two isomeric monoketals **II** and **III**, and also bisketal **IV**. According to the chromatographic data, the approximate weight ratio of the products of mono- and diketalization was 3 : 2. The attempt to carry out the reaction at the molar ratio of compound **I** and ethylene glycol equal 1:1 in order to obtain only monoketals as had been described for unsubstituted diketone [14] was unsuccessful since the formation of significant amounts of bisktal started at the conversion of initial dibromodiketone **I** of 10–15%.

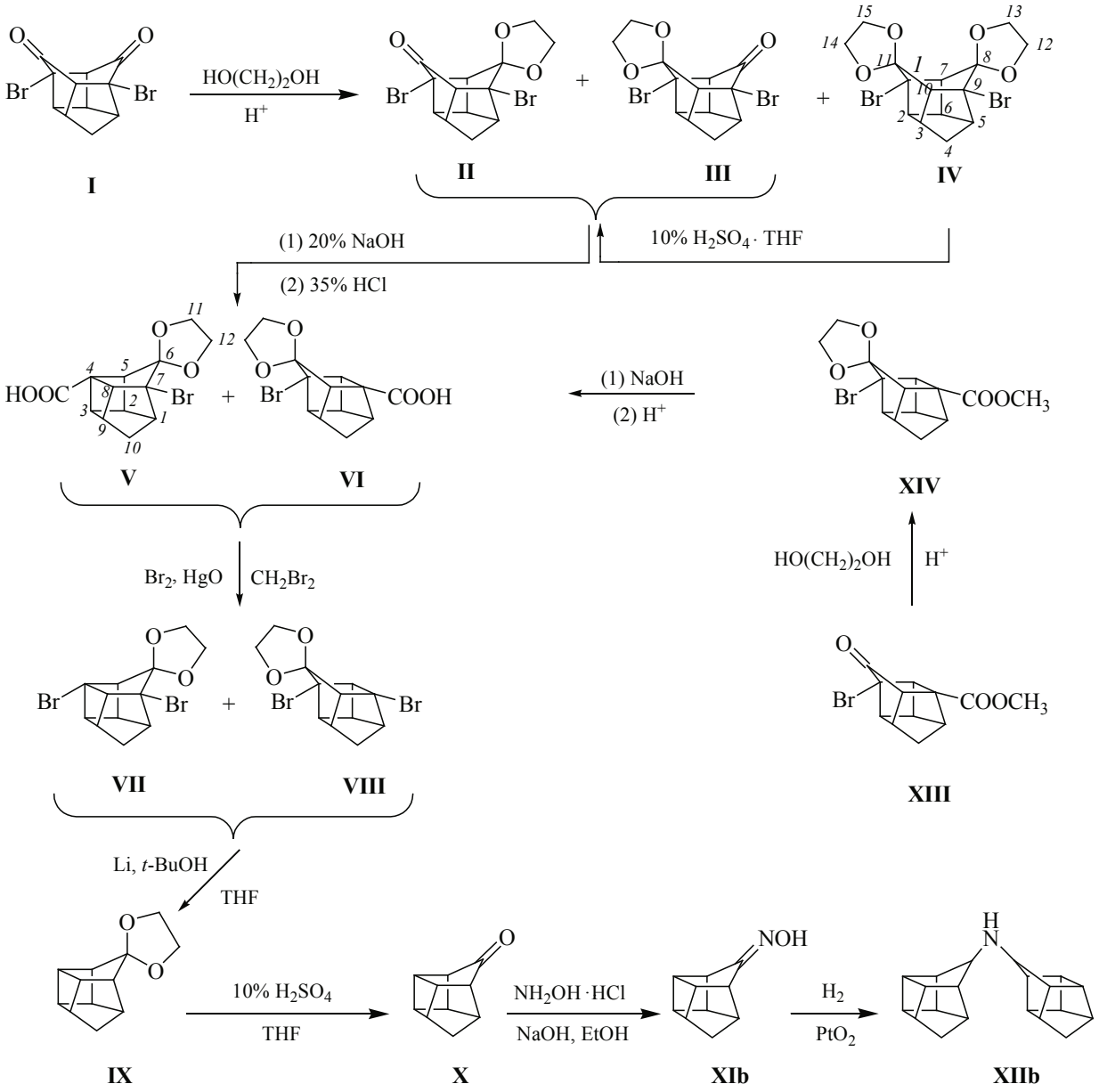
The Faworsky ring contraction performed in concentrated alkali water solutions is a common procedure for the synthesis of more strained homocubanes from their less strained homologs [15, 16]. In the mixture of compounds **II–IV** only monoethylene ketals underwent the reaction giving the corresponding isomeric carboxy derivatives **V** and **VI**, whereas the bisethylene ketal remained intact and therefore was easily filtered off from the reaction mixture. Acids **V** and **VI** were precipitated from the mother liquor by adding concentrated hydrochloric acid under the pH control (4–5). The yield of compounds **V** and **VI** depends on the degree of powdering the ketal mixture before the reaction and on the amount of water used in the treatment of the reaction mixture apparently because of the considerable solubility in water of carboxy derivatives **V** and **VI**.

It turned out that bisethylene ketal of 1,9-dibromope ntacylo[5.4.0.0^{2,6}.$0^{3,10}$.$0^{5,9}$]undeca-8,11-dione (**IV**) was hydrolyzed by a mixture of 10% sulfuric acid and THF at the ratio 4:1, v/v, at 80°C [17] to form quantitatively a mixture of monoethylene ketals without the admixture of diketone **I**. Evidently the hydrolysis of one ethylene ketal protective group proceeds relatively easily due to the considerale stain in compound **IV** arising from the sterical repulsion of the oxolane moieties which is absent in monoketals **II** and **III**. In turn, the hydrolysis of the second group is impeded by the presence of a bromine in the α-position with respect to the carbonyl substituent. This fact is well consistent with the published data on the hydrolysis in the concentrated sulfuric acid of α-bromo-substituted ethylene ketales of the structures of the homocubane and C_2-bishomocybane [15]. The obtained result made it possible to optimize the procedure of the synthesis of isomeric carboxy derivatives **V** and **VI** by performing the partial hydrolysis of diketone bisethylene ketal **IV** directly after the synthesis of the mixture of compounds **II–IV** thus simplifying the treatment of the reaction mixture and increasing the yield of compounds **V** and **VI**.

By the decarboxylation of monoethylene ketals **V** and **VI** by the method of Hunsdiecker–Borodine in Cristol modification [18] with bromine in the boiling dibromomethane in the presence of the red mercury oxide we obtained the mixture of ethylene ketals of 4,7- and 5,8-dibromopentacyclo-[5.3.0.$0^{2,5}$.$0^{3,9}$.$0^{4,8}$]decan-6-one (**VII**) and (**VIII**) respectively.

The ^{13}C NMR spectra of pairs of isomers **V** and **VI**), **VII** and **VIII** contain double sets of signals of the carbon atoms with the intensity ratio ~5 : 1 indicating unequal content of the isomer in the mixture. In order to assign the carbon signals in the ^{13}C NMR spectrum to the definite isomer we carried out an independent synthesis of isomer **VI** from 5-bromo-8-carbomethoxy-pentacyclo[5.3.0.$0^{2,5}$.$0^{3,9}$.$0^{4,8}$]decan-6-one (**XIII**) whose synthesis had been described in [19−21]. The boiling of compound **XIII** in benzene with excess ethylene glycol provided 6-ethylene ketal of 5-bromo-8-carbomethoxpe

Scheme 1.



ntacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one (**XIV**) that was hydrolyzed to 6-ethylene ketal of 5-bromopentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one-8-carboxylic acid **VI**. Acid **VI** was converted into dibromide **VIII** similarly to the procedure of the treatment of the mixture of compounds **V** and **VI**.

Dehalogenation of the mixture of dibromoketal **VII** and **VIII** was carried out by the system lithium–*tert*-butanol in THF. The completeness of the reduction was monitored by the capillary GLC, and the *tert*-butanol was added when required to complete the reaction.

The hydrolysis of ethylene ketal of pentacyclo-[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one (**IX**) by the mixture of 10% sulfuric acid and THF at the ratio 4:1, v/v, at 80°C furnished ketone **X** that by the procedure [22] was converted into pentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one oxime (**XIb**).

The reduction of oxime **XIb** with hydrogen at the atmospheric pressure in methanol in the presence of 3–5% of Adams catalyst at 20°C led to the quantitative formation of di-6-pentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decylamine (**XIIb**).

The high selectivity of the reduction of oxime **XIb** into the bisframework amine **XIIb** prompted us to study the reduction under the same conditions of the oximes of the nearest homologs of pentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}] decan-6-one: pentacyclo-[4.3.0.0^{2,5}.0^{3,8}.0^{4,7}]nonan-9-one (homocubanone) (**XIa**), pentacyclo[6.3.0.0^{2,6}.0^{3,10}.0^{5,9}] undecan-4-one (D_3-trishomocubanone) (**XIc**), and pentacyclo-[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]undecan-8-one (C_S-trishomocubanone) (**XId**). It proved that the oximes of the homocubanone and D_3- trishomocubanone behave analogously to oxime **XIb**, whereas the reduction of the oxime of C_S-trishomocubanone in the presence of 3–5% of catalyst yielded as the main product the corresponding amine, and the dialkylamine formed in the amount not exceeding 5–7%. On increasing the catalyst quantity to 8–10% the dialkylamine prevailed in the reduction product (60–75%).

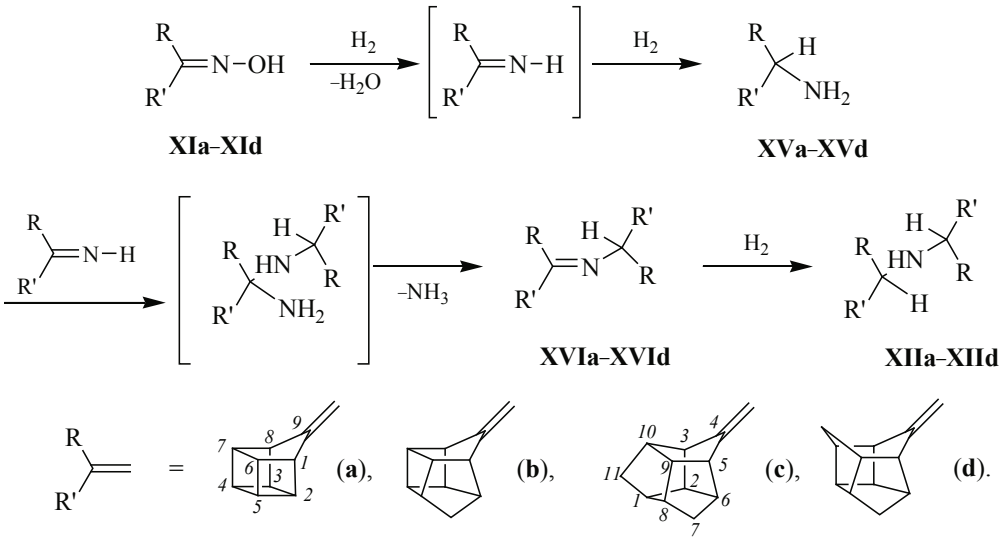
By the data of GC-MS analysis the reaction mixtures after 2–4 h from the start of the process contained the following compounds: initial oximes **XIa–XId**, monoalkylamines **XVa–XVd**, dialkylamines **XIIa–XIId**, and alkylideneimines **XVIa–XVId**. The set of compounds present in the reaction mixture suggests that the reduction of oximes **XIa–XId** proceedes along the pathway considered for the reduction of the oximes from the aliphatic-aromatic series [23, 24].

Oximes **XIa–XId** are distinguished only by the structure of the hydrocarbon residue. In the oximes of homocubanone **XIa**, C_2-bishomocubanone **XIb**, and D_3-trishomocubanone **XIc** the C=N bond belongs to two five-membered cyclic fragments of the framework, whereas in the oxime of C_S-trishomocubanone it belongs to five- and six-membered cyclic fragments, and the six-membered ring is present in the *boat* conformation. It is presumable that the selectivity in reduction of oxime **XId** is decreased due to the steric hindrances arising in the reaction between monoalkylamine and monoalkylimine at the formation of the key intermediate in the synthesis of the secondary amines **XIIa–XIId** (Scheme 2).

Owing to the high internal symmetry of the proper substituent and also due to the C_S-symmetry of the secondary amine the simplest ^{1}H and ^{13}C NMR spectra were observed for di-9-pentacyclo[4.3.0.0^{2,5}.0^{3,8}.0^{4,7}]-nonylamine (**XIIa**). The ^{1}H NMR spectrum contains four singlets with the integral intensity ratio 2:4:2:1, and in the ^{13}C NMR spectrum only four carbon signal are observed.

^{13}C NMR spectrum of amine **XIIb** contains a large number of signals of various intensity complicating its structural analysis. Actually, pentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}] decane (C_2-bisnomocubane), substituted at the secondary carbon atom exists in the form of *syn*- and *anti*-epimers with the latter usually prevailing [25, 26]. It is presumable that amine **XIIb** forms as three isomers as confirmed by the presence in the ^{13}C NMR spectrum of three pairs of carbon nuclei signals with the intensity ratio ~9:3:1 in the region of 66 ppm, belonging to carbon atoms attached to the nitrogen atom. In the ^{1}H NMR spectrum this assumption is confirmed by the presence of three *AB* systems in the region 1.25–1.55 ppm with the same intensity ratio corresponding to the protons at

Scheme 2.



the secondary carbon atoms of the framework fragment.

^{13}C NMR spectrum of di-4-pentacyclo[6.3.0.0^{2,6}.0^{3,10}.0^{5,9}]undecylamine (**XIIc**) consists of the double set of carbon nuclei signals belonging to two diastereomers (*RR/SS* and *RS*) formed from the D_3-symmetric oxime **XIc** in the ratio 1 : 1.

Considering the difficulties in the interpretation of the ^{13}C NMR spectra of amines **XIIb, XIIc** we measured their high-resolution mass spectra to confirm their homogeneity and purity.

Whereas the bisframework amines **XIIa–XIIc** were obtained in the preparative yield no less than 90%, di-8-pentacyclo[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]undecylamine (**XIId**) was obtained in the mixture with the monoalkylamine and was not isolated in the pure state. Therefore the structural assignments were done based on the corresponding mass spectra and the ^{13}C NMR spectrum of the mixture of mono- and dialkylamines in the ratio 2 : 3.

Thus we developed a selective method of the synthesis of di-9-pentacyclo[4.3.0.0^{2,5}.0^{3,8}.0^{4,7}]nonylamine, di-6-pentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decylamine, and di-4-pentacyclo[6.3.0.0^{2,6}.0^{3,10}.0^{5,9}]undecylamine consisting in the reduction of oximes of the corresponding ketones by hydrogen under the atmospheric pressure and room temperature in the presence of the platinum catalyst. It was also shown that the reduction of the oxime of C_S-trishomocubane-8-one under the same conditions resulted in the mixture of the corresponding mono- and dialkylamines. Besides the preparative methods are developed for the synthesis of intermediate compounds that can be used for obtaining diverse mono- and disubstituted derivatives of C_2-bishomocubane.

EXPERIMENTAL

^{1}H and ^{13}C NMR spectra were registered on a spectrometer Bruker DPX-400 at operating frequencies 400.13 and 100.61 MHz respectively, solvent $CDCl_3$, internal reference TMS. GC-MS measurements were performed on an instrument Hewlett Packard 5971A (electron impact 70 eV, mass-selective detector), a chromatograph HP 5890, column HP-5 (5% of phenylmethylsilicone), vaporizer temperature 250°C, oven temperature 60–250°C, heating rate 20 deg/min. GLC analysis was carried out on a capillary chromatograph Shimadzu GC-14B, flame-ionization detector, column Optima-1, vaporizer temperature 275°C, oven temperature 80–250°C, heating rate 20 deg/min. High-resolution mass spectra were measured on an instrument Finnigan MAT 95.

1,9-Dibromopentacyclo[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]-undeca-8,11-dione (I) was obtained from 26.4 g (0.1 mol) of 2,5-dibromo-*p*-benzoquinone by procedure [11]. Yield 29.2 g (89%), mp 185–186°C. Spectral characteristics were identical to those published in [27].

Reaction of 1,9-dibromopentacyclo[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]undeca-8,11-dione (I) with ethylene glycol. A mixture of 15 g (0.045 mol) of compound **I**, 12.4 g (0.2 mol) of ethylene glycol, and 0.3 g of *p*-toluenesulfonic acid monohydrate in 250 ml of anhydrous benzene was boiled with a Dean–Stark trap for 6 h. The benzene solution was washed in succession with water, 10% water solution of sodium carbonate, and with brine, dried with Na_2SO_4, the solvent was distilled off in a vacuum. We obtained 17.2 g of viscous oily mixture of substances **II–IV** that crystallized within 24 h.

Ethylene ketals of 7-bromopentacyclo-[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one-4-carboxylic acid (V) and 5-bromopentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one-8-carboxylic acid (VI) were obtained by boiling 11.8 g of finely dispersed mixture of ketals **II–IV** in 160 ml of 20% water solution of KOH at stirring over 4 h. The reaction mixture was cooled, bisethylene ketal **IV** was filtered off, washed on the filter with water (2 × 10 ml), and dried in air till constant weight. We obtained 4.8 g of colorless or slightly colored crystals. The filtrate was extracted with ethyl ether, the water layer was returned to the reactor, and at vigorous stirring and cooling with an ice–NaCl mixture a calculated quantity of sulfuric acid was added dropwise maintaining the temperature of the reaction mixture below 10°C. When the pH of the mixture attained 4–5 the separated precipitate was filtered off, washed with ice water (2 × 10 ml), and dried in air. Yield of the mixture of compounds **V** and **VI** 4.9 g.

(a) A mixture of 4.8 g (0.0114 mol) of bisethylene ketal **IV**, 120 ml of 10% sulfuric acid, and 30 ml of THF was heated at 80°C with stirring for 3–4 h. The reaction mixture was cooled, extracted with dichloromethane (3 × 100 ml). The organic layer was washed with water and 10% water solution of sodium carbonate, dried with Na_2SO_4, the solvent was removed in a vacuum. Yield 4.2 g (97%) of a mixture of monoketals **II** and **III**. After the reaction with aqueous alkali we obtained 3.15 g (90%) of the mixture of carboxylic acids **V** and **VI**. Overall yield yield 8.05 g (83% calculated on compound **I**).

(b) A mixture of 5.4 g of ethylene ketals **II–IV** was hydrolyzed by procedure *a* described above for

bisethylene ketal **IV**. Yield 5.05 g of a mixture of monoketals **II** and **III**. After the reaction with aqueous alkali we obtained 4 g of the mixture of carboxylic acids **V** and **VI** (90% calculated on compound **I**).

Ethylene ketal of 5-bromopentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one-8-carboxylic acid (VI) was obtained by dissolving 0.5 g of NaOH in 0.5 ml of water, adding 12.5 ml of methanol and to the solution thus prepared adding a solution of 1.24 g (3.8 mmol) of ethylene ketal of 7-bromo-4-carbomethoxypentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one (**XIV**) in 7 ml of methanol. The reaction mixture was stirred at room temperature over 15 h, methanol was distilled off in a vacuum, the residue was dissolved in 4 ml of water, and at stirring while cooling the concn. sulfuric acid was added dropwise till weakly acidic pH. The precipitate was filtered off, washed on the filter with ice water (2 × 3 ml), and dried in air. Yield 1.01 g (85%), mp 138–140°C (from hexane). ^{1}H NMR spectrum, δ, ppm: 1.55 d, 1.90 d (*AB* system, 2H, CH_2, *J* 12 Hz), 2.50 br.s (1H, CH), 2.95–3.32 m (5H, CH), 3.95–4.35 m (4H, CH_2), 10.35 br.s (1H, COOH). ^{13}C NMR spectrum, δ, ppm: 36.9 (C^3), 40.3 (C^{10}), 44.9 (C^1), 46.0 (C^9), 47.1 (C^7), 50.8 (C^2), 52.1 (C^4), 55.9 (C^8), 62.8 (C^5), 66.0 (C^{11}), 66.6 (C^{12}), 119.3 (C^6), 176.1 (C^{13}). Mass spectrum, *m/z* (I_{rel}, %): 314 (18.5) [M(^{81}Br)]$^+$, 312 (18.3) [M(^{79}Br)]$^+$, 297 (13.6) [M – OH(^{81}Br)]$^+$, 295 (13.9) [M – OH(^{79}Br)]$^+$, 269 (43.6) [M – COOH(^{81}Br)]$^+$, 267 (45.1) [M – COOH(^{79}Br)]$^+$, 233 (100) [M – Br]$^+$, 187 (15.5), 143 (22.2), 116 (48.6), 115 (68.1), 77 (14.8) $[C_6H_5]^+$, 73 (29.3) $[C_3H_5O_2]^+$. Found, %: C 49.79; H 4.17. $C_{13}H_{13}BrO_4$. Calculated, %: C 49.86; H 4.18. *M* 313.144.

Ethylene ketals of 4,7-dibromopentacyclo-[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one (VII) and 5,8-dibromopentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one (VIII). A solution of 9 g (3 ml, 0.056 mol) of bromine in 50 ml if dibromomethane was added dropwise to a vigorously stirred solution of 11.5 g (0.037 mol) of the mixture of carboxylic acids **V** and **VI** in 120 ml of boiling dibromomethane in the presence of 8.9 g (0.041 mol) of red mercury oxide. The mixture was boiled for 3 h, cooled to the room temperature, the separated precipitate was filtered off and washed on the filter with dibromomethane (2 × 10 ml). Dibromomethane was distilled off in a vacuum of a water-jet pump, the residue was treated with boiling hexane (4 × 75 ml), hexane was evaporated in a vacuum, and the residue was subjected to column chromatography on silica gel, eluent hexane–ethyl ether, 9 : 1 v/v. The solvents were removed in a vacuum. Yield 12.4 g (96%) of the mixture of compounds **VII**, **VIII**.

Ethylene ketal of 5,8-dibromopentacyclo-[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one (VIII) was obtained from 0.75 g (0.0024 mol) of ethylene ketal of bromoacid **VI** by the above described procedure. Yield 0.75 g (90%), mp 57–58°C (from methanol). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.45 d, 1.98 d (*AB* system, 2H, CH_2, *J* 11 Hz), 2.40 br.s (1H, CH), 2.90–3.30 m (5H, CH), 3.92–4.36 m (4H, CH_2). ^{13}C NMR spectrum, δ, ppm: 37.4 (C^3), 39.1 (C^{10}), 45.5 (C^1), 50.7 (C^9), 53,1 (C^7), 55.9 (C^2), 58.0 (C^4), 59.1 (C^8), 62.6 (C^5), 65.9 (C^{11}), 66.0 (C^{12}), 118.4 (C^6). Mass spectrum, *m/z* (I_{rel}, %): 350 (5.4) [M(^{81}Br)]$^+$, 348 (10.7) [M(^{81}Br^{79}Br)]$^+$, 346 (5.3) [M(^{79}Br)]$^+$, 269 (88.1) [M – Br(^{79}Br)]$^+$, 267 (91.7) [M – Br(^{81}Br)]$^+$, 223 (13.3), 187 (32.5), 144 (21.2), 116 (100), 115 (96.5), 66 (20.8) $[C_5H_6]^+$. Found, %: C 41.31; H 3.51. $C_{12}H_{12}Br_2O_2$. Calculated, %: C 41.41; H 3.48. *M* 348.030.

Ethylene ketal of pentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]-decan-6-one (IX) was obtained from 10.8 g (0.031 mol) of the mixture of dibromides **VII, VIII** along the procedure [28]. Yield 5.6 g (95%), bp 123–126°C (14 mm Hg) [26]. Spectral characteristics were identical to published in [29].

Pentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one (X) was obtained from 5.5 g (0.029 mol) of ketal **IX** by the method [17]. Yield 4.1 g (97%), mp 126–127°C. Spectral characteristics were identical to those published in [30].

Pentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one oxime (XIb) was obtained from 3.65 g (0.25 mol) of ketone **X** by the procedure [31]. Yield 3.54 g (88%), mp 99–100°C. Spectral characteristics were identical to those published in [31].

Di-6-pentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decylamine (XIIb). To a solution of 0.32 g (0.02 mol) of oxime **XIb** in 30 ml of anhydrous methanol was added a catalytic quantity of platinum(IV)oxide. The reactor flask was several times flushed with hydrogen and was left at stirring at the hydrogen pressure in the gasometer for 24 h. The reaction mixture was filtered from the catalyst through a silica gel bed, methanol was evaporated in a vacuum, the residue was dissolved in a minimum volume of ethyl ether, and the amine was precipitated by the gradual addition of a saturated solution of gaseous hydrogen chloride in ethyl ether. The obtained amine hydrochloride was treated with 10% water solution of KOH, extracted with ethyl ether, the extract was dried with KOH, the solvent was evaporated in a vacuum. Yield

0.25 g (90%), mp 138–150°C. ^{1}H NMR spectrum, δ, ppm: 1.25–1.33 m, 1.50 d (part of *AB* system. *J* 12 Hz), 1.60–1.70 m (4H, CH_2), 2.65–3.63 m (19H, CH, NH). ^{13}C NMR spectrum, δ, ppm: 36.6, 36.7, 36.8, 37.1, 37.8, 37.9, 38.0, 38.2, 38.6, 38.7, 39.5, 39.6, 39.7, 39.8, 39.9, 40.0, 40.9, 41.0, 41.1, 41.2, 41.3, 41.4, 41.5, 41.6, 41.6, 41.7, 41.7, 41.8, 41.9, 42.1, 42.2, 42.2, 42.3, 42.4, 42.9, 45.1, 45.2, 45.3, 45.4, 45.5, 48.2, 48.3, 48.5, 48.6, 49.0, 49.2, 49.4, 49.5, 49.9, 66.0, 66.2, 66.3, 66.4, 66.7, 67.2. Mass spectrum, *m/z* (I_{rel}, %): 277 (100) $[M]^+$, 212 (53.4) $[M - C_5H_5]^+$, 211 (26.9) $[M - C_5H_6]^+$, 160 (27.5), 146 (21.8) $[M - C_{10}H_{11}]^+$, 131 (79.3) $[C_{10}H_{11}]^+$, 116 (34.8), 115 (29.3), 91 (82.3) $[C_7H_7]^+$, 65 (11.8) $[C_5H_5]^+$. Found *M* 277.1827. $C_{20}H_{23}N$. Calculated *M* 277.1830.

Compounds **XIIa, XIIc** were obtained similarly.

Di-9-pentacyclo[4.3.0.0^{2,5}.0^{3,8}.0^{4,7}]nonylamine (XIIa) was obtained from 0.3 g (0.002 mol) of oxime **XIa** [22]. Yield 0.23 g (92%), mp 157–160°C. ^{1}H NMR spectrum, δ, ppm: 3.22 s (4H, CH), 3.45 s (4H, CH), 3.52 s (8H, CH), 3.79 s (1H, NH). ^{13}C NMR spectrum, δ, ppm: 40.7 ($C^{4,5}$), 41.2 ($C^{2,3,6,7}$), 43.9 ($C^{1,8}$), 72.0 (C^9). Mass spectrum, *m/z* (I_{rel}, %): 249 (6.0) $[M]^+$, 132 (13.4) $[M - C_9H_9]^+$, 130 (11.9) $[C_9H_8N]^+$, 117 (39.5) $[C_9H_9]^+$, 115 (100.0) $[C_9H_7]^+$, 91 (87.9) $[C_7H_7]^+$, 77 (27.9) $[C_6H_5]^+$, 65 (36.4) $[C_5H_5]^+$. Found, %: C 86.61; H 7.72. $C_{18}H_{19}N$. Calculated, %: C 86.70; H 7.68. *M* 249.350.

Di-4-pentacyclo[6.3.0.0^{2,6}.0^{3,10}.0^{5,9}]undecylamine (XIIc) was obtained from 0.35 g (0.002 mol) of oxime **XIc** [32]. Yield 0.27 g (90%), mp 161–170°C. ^{1}H NMR spectrum, δ, ppm: 1.25–1.33 m (6H, CH_2), 1.48–1.62 m (2H, CH_2), 1.98–2.33 m (9H, CH), 2.37–2.65 m (5H, CH), 2.87 s (1H, CH), 2.97 s (1H, CH), 3.32 s (2H, CH). ^{13}C NMR spectrum, δ, ppm: 33.1, 33.2, 33.3, 40.9, 41.3, 41.5, 41.6, 44.4, 44.5, 44.6, 47.4, 47.5, 47.6, 47.8, 48.3, 49.3, 49.9, 61.9, 62.8. Mass spectrum, *m/z* (I_{rel}, %): 305 (100) $[M]^+$, 304 (58.7) $[M - H]^+$, 240 (11.7) $[M - C_5H_5]^+$, 239 (39.2) $[M - C_5H_6]^+$, 238 (28.0), 160 (25.2) $[M - C_{11}H_{13}]^+$, 145 (11.1) $[C_{11}H_{13}]^+$, 117 (10.9), 91 (13.2) $[C_7H_7]^+$, 79 (61.0), 77 (15.1) $[C_6H_5]^+$, 67 (21.6). Found *M* 305.2143. $C_{22}H_{27}N$. Calculated *M* 305.2156.

Ethylene ketal of 5-bromo-8-carbomethoxypentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]decan-6-one (XIV). In 80 ml of benzene was dissolved 1.7 g (0.006 mol) of 5-bromo-8-carbomethoxypentacyclo-[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}] decan-6-one (**XIII**) [21] and 1.1 g (1.0 ml, 0.017 mol) of ethylene glycol, and 20 mg of *p*-toluenesulfonic acid monohydrate was added. The mixture was boiled with a Dean-Stark trap till the water liberation stopped (4–5 h). The reaction mixture was washed with water and with 10% sodium carbonate solution, dried with Na_2SO_4, the solvent was distilled off in a vacuum. Yield 1.8 g (92%), mp 53–54°C (from methanol). ^{1}H NMR spectrum, δ, ppm: 1.53 d, 1.88 d (система *AB*, 2H, CH_2, *J* 12 Hz), 2.54 br.s (1H, CH), 2.92–3.02 m (2H, CH), 3.05–3.15 m (2H, CH), 3.25 t (1H, CH, *J* 3 Hz), 3.73 s (3H, CH_3) 3.88–4.32 m (4H, CH_2). ^{13}C NMR spectrum, δ, ppm: 37.0 (C^3), 40.3 (C^{10}), 44.7 (C^1), 46.7 (C^9), 46.8 (C^7), 50.9 (C^2), 52.0 (C^4), 52.1 (C^8), 55.9 (C^5), 63.3 (OCH_3), 65.9 (C^{11}), 66.4 (C^{12}), 119.1 (C^6), 173.1 (COO). Mass spectrum, *m/z* (I_{rel}, %): 328 (18.0) $[M(^{81}Br)]^+$, 326 (18.2) $[M(^{79}Br)]^+$, 297 (8.6) $[M - OCH_3(^{81}Br)]^+$, 295 (8.5) $[M - OCH_3(^{79}Br)]^+$, 269 (58.2) $[M - COOCH_3(^{81}Br)]^+$, 267 (55.1) $[M - COOCH_3(^{79}Br)]^+$, 247 (100) $[M - Br]^+$, 203 (14.5), 187 (20.1), 143 (18.5), 116 (44.5), 115 (56.4), 73 (20.3) $[C_3H_5O_2]$. Found, %: C 51.40; H 4.57. $C_{14}H_{15}BrO_4$. Calculated, %: C 51.40; H 4.62. *M* 327.170.

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