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Products of Endic Anhydride Reaction with Cyclic Amines and Their Heterocyclization

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Abstract—Products of reaction between bicyclo[2.2.1]hept-5-ene-*endo*-*endo*-2,3-dicarboxylic anhydride (endic anhydride) and cyclic amines were obtained. By an example of one of amido acids a conformational analysis was performed and character of hydrogen bonds was studied using quantum-chemical calculations by PM3 procedure. *endo*-3-(4-Antipyrylcarbomoyl)-bicyclo[2.2.1]hept-5-ene-endo-2-carboxylic acid with a secondary amide group was converted into the corresponding carboximide which was epoxidized by performic acid.

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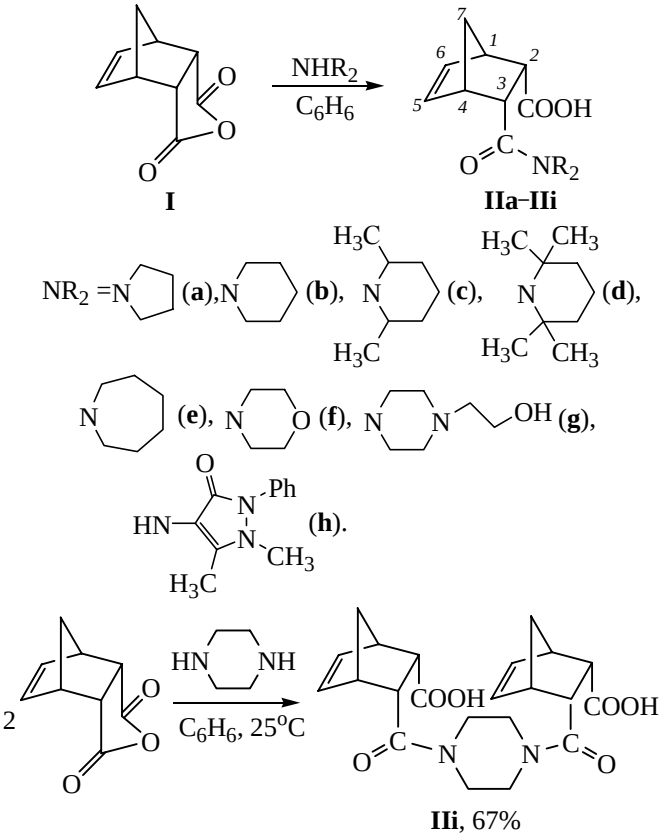
In contrast to numerous carboximides obtained with the use of bicyclo-[2.2.1]hept-5-ene-*endo*,*endo*-2,3-dicarboxilic anhydride (endic anhydride) (**I**), amido acids based thereon are hardly studied [1–5]. It is known that bicyclo[2.2.1]hept-5-ene-*endo*,*endo*-2,3-dicarboxylic acids N-alkylamides were successfully applied as components of repellent compositions [6] and as agents endowed with sedative activity [7]. The corresponding arylamides are present in the composition of a complex herbicide for cotton plant protection [8], their sodium salts facilitate the sprouting of plant seeds [9]. The spectral parameters of amido acids were not reported, The known amido acids were obtained by heating reagents in alcohol [10], acetonitrile [11], or tetrahydrofuran [12].

In this study were investigated endic anhydride reactions with nonaromatic cyclic amines (pyrrolidine, piperidine, its 2,6-dimethyl- and 2,2,6,6-tetramethyl derivatives, hexamethyleneimine, morpholine, piperazine, and N-hydroxyethylpiperazine). For comparison a reaction was studied of anhydride **I** with a primary amine (aminoantipyrine).

The reaction of piperazine with a double molar excess of anhydride **I** led to the formation of amide **IIi** containing two norbornene fragments.

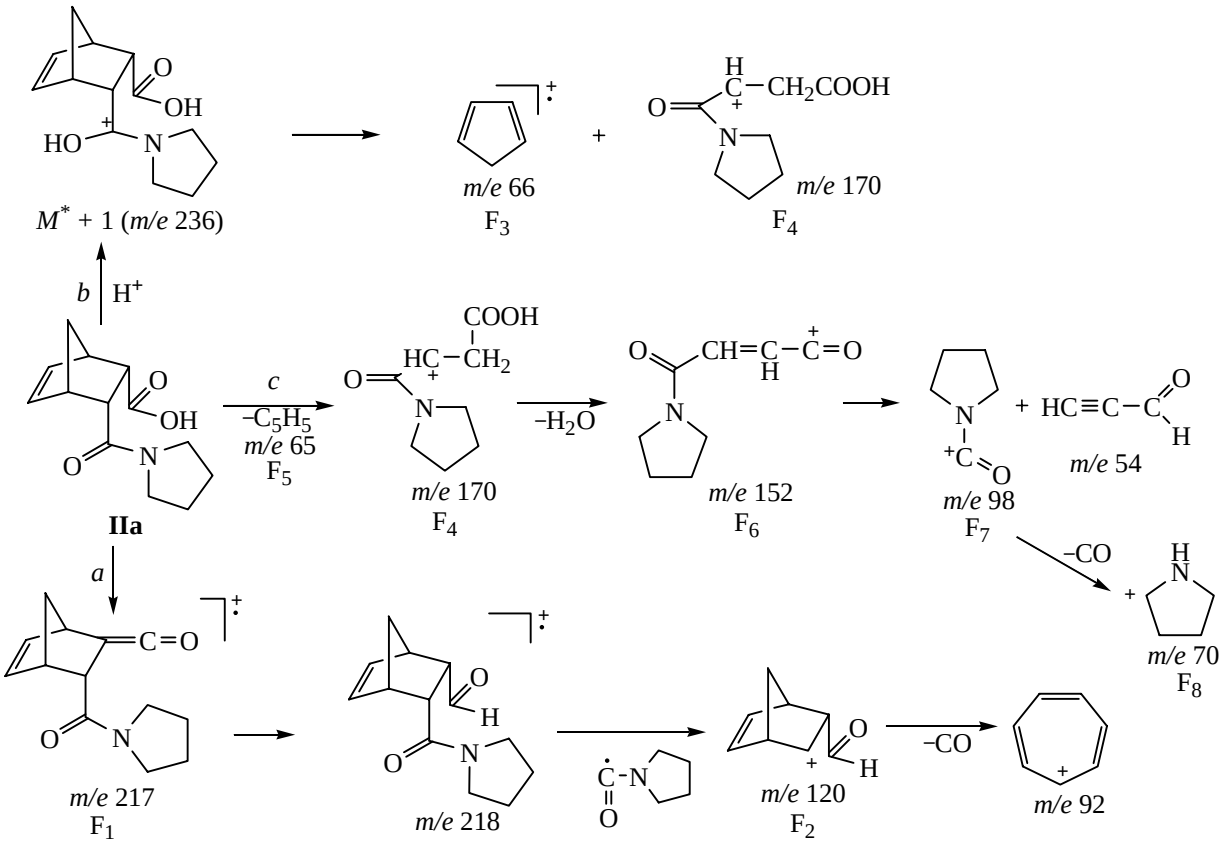


Amido acids **IIa–IIh** were obtained by reaction of equimolar amounts of reagents in benzene solution (TLC monitoring). The synthesis of amido acids **IIa, IIb, IIe**, and **IIf** completed within 24 h, the preparation of compound **IIc** required 4 days. We failed to obtain amido acid **IId** in the cold, the IR spectrum of the product contained absorption bands in the region 2650–2510 and 1460–1390 cm^{-1} indicating the formation of an amine salt instead of amide. To obtain the latter we were obliged to boil the reaction mixture for 7 h. The reaction with the primary amine to synthesize compound **IIh** proceeded in the cold for several days.

IR spectra of compounds contain absorption bands of the amide moiety in the regions 1665–1620 (ν CO), 1280–1250 (ν CN), 3480–3428 cm^{-1} (ν NH) and of carboxy group (1745–1720 cm^{-1}). The unsaturated fragment is revealed by bands in the regions 3076–3054 and 732–707 cm^{-1} corresponding to the stretching and bending vibrations of =C–H bonds respectively [13]. The bands of stretching vibrations of the strained double bond (1575–1550 cm^{-1}) are weak and in the spectrum of the secondary amide **IIh** they are overlapped by NH group absorbance [14].

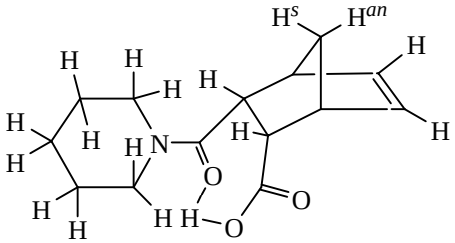
The structure of amido acids was confirmed by ^1H and ^{13}C NMR spectra. ^1H NMR spectra of amido acids contain all the expected signals: of olefin protons H^5 and H^6 in the region 5.91–6.37 ppm, of bridgehead protons H^1 and H^4 in the region 2.92–3.25 ppm, and of protons H^2, H^3 close to the carbonyl groups of amido acids (3.10–3.72 ppm). Protons $H^{2,3}$ in the spectra of compounds **IIa–IIh** are nonequivalent, and to their coupling correspond vicinal constants 8.1 and 9.6 Hz confirming the *exo*-orientation of these protons in the framework. Closely located bridging protons H^{7s} and H^{7an} (1.14–1.39 ppm) give signals split by mutual coupling, J 8.0–8.4 Hz. The high symmetry of the piperazine substituents in compound **IIi** should be stressed resulting in superposition of the respective pairs of signals belonging to the norbornene framework.

As in ^1H NMR spectra, in ^{13}C NMR spectra of amido acids **IIb** and **IIc** a coincidence is observed of signals from C^5 and C^6, C^1 and C^4, C^2 and C^3, and also of carbonyl groups signals. In the spectra of the other amido acids nonequivalent carbon signals from carbonyl groups appear, and in the spectra of compounds **IIa** and **IIh** the carbon atoms of norbornen framework are nonequivalent.



For amido acid **IIa** we investigated its fragmentation under electron impact. It involves dehydration to form ion F_1, a homolysis of C–C bond leading to fragment ion F_2 (*m/e* 120) (path *a*). Path *b* included in the first stage a protonation giving ion $M^* + 1$ which suffered a retrodiene decomposition to F_3 (*m/e* 66) and F_4 (*m/e* 170). The latter apparently formed also from a nonprotonated molecule as showed the presence in the mass spectrum of an ion peak F_5 (*m/e* 65) (path *c*). Further transformations of ion F_4 include the formation of ions F_6 (*m/e* 152) and F_7 (*m/e* 98); the latter in its turn is able to fragment giving ion F_8 (*m/e* 70) resulting from the heterolysis of the C–N bond.

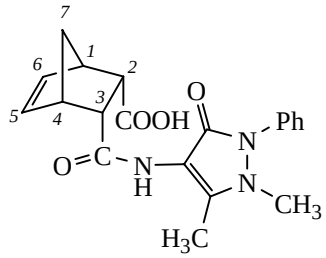
Amido acids contain in their structure conformationally mobile moieties located in the zone of influence of a bulky framework, and the conformation of the molecule can affect the chemical behavior of the reaction sites. For special attention calls the stabilization of the amido acid molecule at hydrogen bonds formation, whose energy was estimated applying semiempirical quantum-chemical method PM3 [15]. The conformers of amido acid **IIb** are distinguished by orientation of the fragments of carboxy and carboxamide groups with respect to the norbornene framework. The variation of angles $NC^8C^2C^4$ and $OC^9C^3C^1$ allowed a conclusion on the highest thermodynamic stability of conformer **III** with an intramolecular hydrogen bond between the hydrogen of the carboxy group and the oxygen from the carboxamide moiety (O–H···O=C); the distance of the hydrogen bond was estimated at 1.770 A. For this structure a characteristic location of two carbonyl groups in nearly perpendicular planes was found and spatial removal from the carbon framework in the equatorial direction of the nitrogen-containing heterocycle existing in the *chair* conformation. Next in stability (difference in heats of formation equal 2.50 kcal mol^{-1}) was the structure with no hydrogen bonds; the formation of hydrogen bond O–H···N proved to be less thermodynamically feasible.



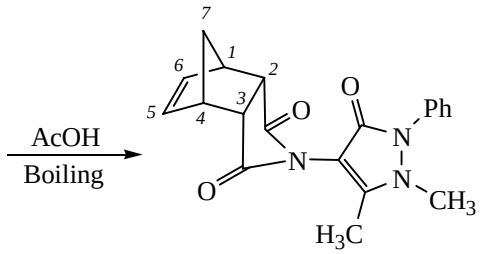
III

Amido acids possess several reactive sites (a strained double bond, a carboxy and a carboxamide groups) and are capable involthing these sites to transform into other groups of compounds. By boiling in glacial acetic acid amido acid **IIh** was converted into the corresponding carboxamide **IV**.

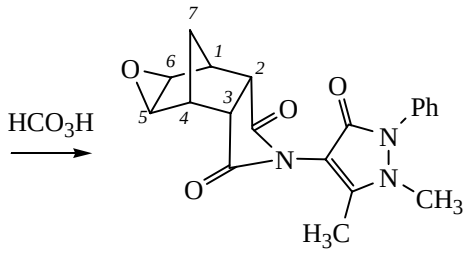
Imide **IV** was subjected to epoxidation with performic acid obtained *in situ* from 98% formic acid and 50% water solution of hydrogen peroxide. The successful application of the performic acid was ensured by its high acidity and reactivity as an electrophilic oxidative reagent with respect to substrates containing two electron-withdrawing substituents that essentially decreased the nucleophilic reactivity of the olefin. The electron-withdrawing substituents due to their significant *–I*-effect prevent stabilization of cation intermediates and therewith the opening of the epoxy ring of the formic acid and occurrence of rearrangements accompanying this process. Owing just to the substrates structure the hydroxylating reagent (performic acid) in these reactions shows high epoxidizing power [16]. In the IR spectra of imide **IV** and its epoxy derivative **V** absorption bands are present of symmetric and antisymmetric vibrations of the carbonyl groups in the regions 1758–1735 and 1705–1685 cm^{-1} [14]. The spectrum of epoxide **V** contains an absorption



IIh



IV

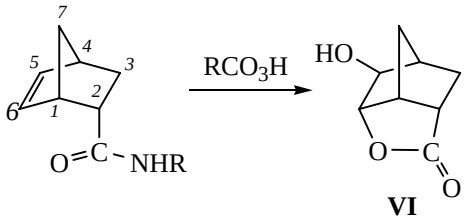


V

band characteristic of epoxynorbornanes in the region 858 cm^{-1} belonging to the stretching vibrations of C–O bond in the epoxynorbornane fragment [14]. In the IR spectra of imide **IV**, epoxide **V**, as well as of the corresponding amido acid **IIh** the bands are present from the vibrations of bonds in the heterocyclic fragments.

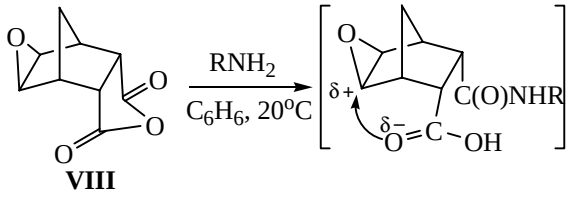
Unlike the imides from the norbornene series whose reactions with organic peracids was freaquently discussed in special publications [5, 17], oxidation of amido acids nearly was not investigated formerly. The only instance was the study of oxidation of an amido acid with a phenylethyl group whose products were not identified [2].

The oxidation of amido acids may lead both to epoxy derivatives and to products of their heterocyclization involving carboxy and amide groups. Events of such heterocyclization of substituted norbornenes are known, in particular, lactone **VI** was obtained on epoxidation of various bicyclo-[2.2.1]hept-5-ene-2-carboxamides with the *endo*-orientation of a substituent under a considerable excess (4:1) of peracids [18, 19].

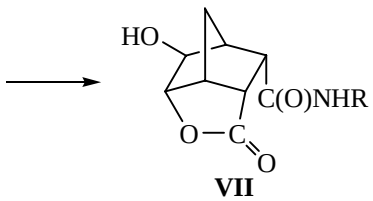


VI

Amidolactones **VII** also formed in reaction with amines (RNH_2, R = H, Ph, CH_2Ph) of epoxidized endic anhydride **VIII** [20]. The reactions occurred under mild conditions in a weak alkaline medium due to the presence of amines.



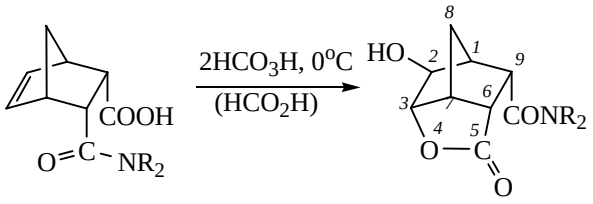
VIII



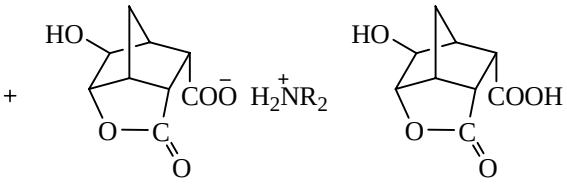
VII

To oxidize the amido acids we chose as in reaction with imide **IV** the performic acid obtained *in situ* from 98% formic acid and 50% water solution of hydrogen peroxide. Oxidation of amido acids **IIb–IIg** and **IIi** was carried out at 0°C with TLC monitoring in the presence of a double molar excess of the oxidant (the oxidation of amido acid **IIi** was done in a solution of excess performic acid in formic acid).

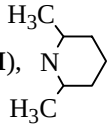
Oxidation of amido acids **IIb–IIe** led to the formation of two types of compounds: amidolactones **IX–XII** and salts **XIII–XVI** of lactonoacid **XVII** and the corresponding amines.

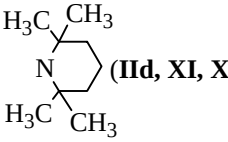


IIb–IIe **IX–XII**

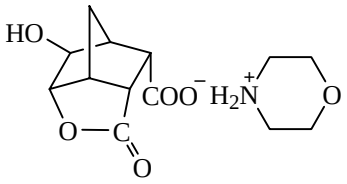


XIII–XVI **XVII**

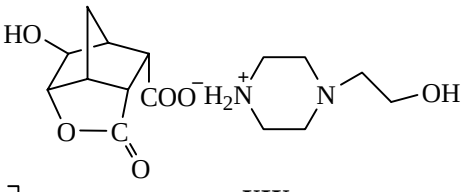
NR_2 =  (**IIb, IX, XIII**),  (**IIc, X, XIV**),

 (**IId, XI, XV**),  (**IIe, XII, XVI**).

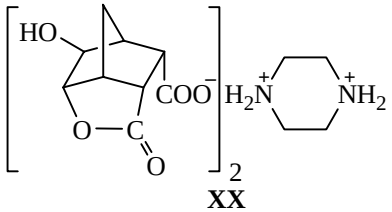
The only reaction products of oxidizing amido acids **IIf, IIg**, and **IIi** were salts **XVIII–XX**.



XVIII



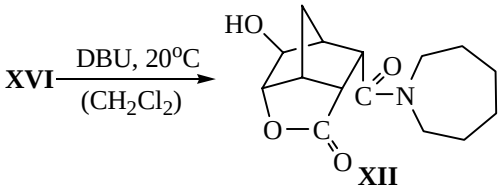
XIX



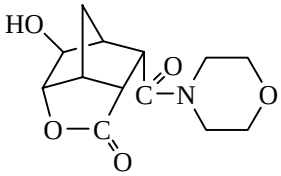
XX

To elucidate the contribution of the nature of the peracid a reaction of amido acid **IIe** was performed with a double excess of peracetic acid obtained *in situ* from glacial acetic acid and 50% water solution of hydrogen peroxide. Reaction was carried out for 10 days in glacial acetic acid at room temperature with TLC monitoring. The only reaction product obtained in 71% yield was salt **XVI**.

Inasmuch as in experiments on amido acids oxidation the amidolactones were not the sole products, and the attempts on chromatographic separation of mixtures of amidolactones and salts of acid **XVII** failed we converted salts **XVI** and **XVIII** into amidolactones **XII** and **XXI** by treating with dicyclohexylcarbodiimide (DCC) in dichloromethane for 3–7 days at room temperature (yields 73 and 80% respectively). The experiments were carried out with salts of acid **XVII** with hexamethyleneimine **XVI** and morpholine **XVIII** obtained by oxidation.



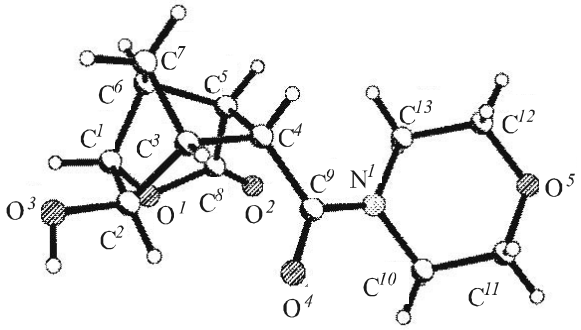
XII



XXI

Using the same dehydrating agent (DCC) we successfully converted the mixture of 38% of amidolactone **XII** and 62% of salt **XVI** obtained by oxidation of amide **IIe** with performuc acid prepared in situ into amidol-actone **XII** in 75% yield. We calculated the quantity of DCC required for the reaction taking into account the composition of the mixture determined using ^{1}H NMR spectrum.

Structure of compound **XXI** was proved by X-ray diffraction analysis (see the figure). The five-membered heterocycle is present in an *envelope* conformation. Deviation of C^6 atom from the root-mean-square plane of the other atoms of the ring is –0.60 Å. Both five-membered carbocycles included into the framework compound are also in the *envelope* conformation. Deviation of C^7 atom from the root-mean-square plane of the other atoms for the ring C^1–C^3, C^6, C^7 amounts to –0.84 A, and for the ring C^3–C^7, to 0.84 Å. The hydroxy



Structure ofe *endo*-9-morpholinocarbonyl-*exo*-2-hydroxy-4-oxatricyclo[4.2.1.0^{3,7}]nonan-5-one (**XXI**) according to the data of X-ray diffraction analysis

group at C^2 atom of the bicycloheptane fragment has *exo*-orientation, and the substituent attached to C^4 atom, *endo*-orientation [torsion angles $O^3C^2C^3C^4$ 179.4(5)° and C^4C^9 –67.4(2)°]. Therewith formed a weak intramolecular- hydrogen bond C^2–$H^2\cdots O^4$ 2.37 Å (H···O 2.37 Å, CH···O 119°). The carbonyl group of the substituent at C^4 atom is virtually coplanar with the C^3–C^4 bond of bicycloheptane fragment [torsion angle $C^3C^4C^9O^4$ 2.5(2)°], and oxazine ring is in *ap*-conformation relative to this bond and is so turned that the C^{13}–N^1 bond is practically coplanar with C^4–C^9 bond [torsion angles $C^3C^4C^9N^1$ –176.1(2)° and $C^{13}N^1C^9C^4$ 6.6(3)°]. This orientation of the oxazine ring results in relatively strong repulsion between the atoms of the bicycloheptane fragment and of the heterocycle {shortened intramolecular contacts $H^4\cdots C^{13}$ 2.79 Å (sum of van der Waals raddi is 2.87 A [21]), $H^4\cdots H^{13a}$ 2.14 A (2.34 Å), $H^5\cdots H^{13a}$ 2.20 A (2.34 A), $H^{13a}\cdots C^4$ 2.47 A (2.87 Å), $H^{13a}\cdots C^5$ 2.66 Å (2.87 Å)}. Apparently, just this steric strain caused a considerable elongation of C^4–C^5 bond [1.580(3) A] as compared to an average value for C_{sp3}–C_{sp3} bond 1.542 Å [22]. The analysis of bond distances in the framework compounds of this type showed that the respective bond always suffered elongation if a substituent was present at this bond [23–26]. The oxazine ring exists in the *chair* conformation (folding parameters [27]: *S* 1.16, Θ 1.6°, Ψ 25.2°). Deviations of N^1 and O^5 atoms from the root-mean-square plane of the other atoms of the ring are –0.63 and 0.64 Å respectively.

In the crystal the molecules of compound **XXI** form dimers owing to intermolecular hydrogen bond O^3–$HO^3\cdots O^{4'}$ [(–*x*, –*y*, 1 – *z*) H···O' 1.86 A, O–H···O' 172°] that also assists in elongating O^4–C^9 bond to 1.240(2) Å compared to its average value of 1.210 Å. In the crystals shortened intramolecular contacts were found $H^1\cdots H^{11a'}$

(0.5 – *x*, –0.5 + *y*, 1.5 – *z*) 2.19 Å (2.34 Å), $H^{3}\cdots C^{9'}$ (1 – *x*, –*y*, 1 – *z*) 2.78 Å (2.87 Å), $H^{5}\cdots H^{7an'}$ (0.5 + *x*, –0.5 – *y*, 0.5 + *z*) 2.29 A (2.34 Å), and $H^{6}\cdots C^{11'}$ (1.5 – *x*, –0.5 + *y*, 1.5 – *z*) 2.78 A (2.87 Å).

The structure of other compounds was studied by IR and ^{1}H NMR spectroscopy.

The IR spectra of products of amido acids oxidation contain a broad absorption band in the region 3470–3355 cm^{-1} [ν(OH)], and also absorption band of two carbonyl groups, lactone (1795–1770 cm^{-1}) and amide (1640–1620 cm^{-1}) ones [14]. The stretching vibrations of the fragment C–O–C included into the five-membered lactone ring appear as a narrow strong band in the region 1030–1014 cm^{-1}. A set of bands in the spectra confirms the presence in the oxidation products of amido acids of substances with salt character: First of all these are broad bands or a group of narrow bands in the region 2645–2480 cm^{-1} ("ammonium band" of H_2N^+ group), and also the bands of antisymmetric and symmetric vibrations of carboxylate anion in the regions 1640–1590 and 1370–1348 cm^{-1}. The scissors vibration of the latter gives rise to a well-defined medium band in the region 775–760 cm^{-1} [14].

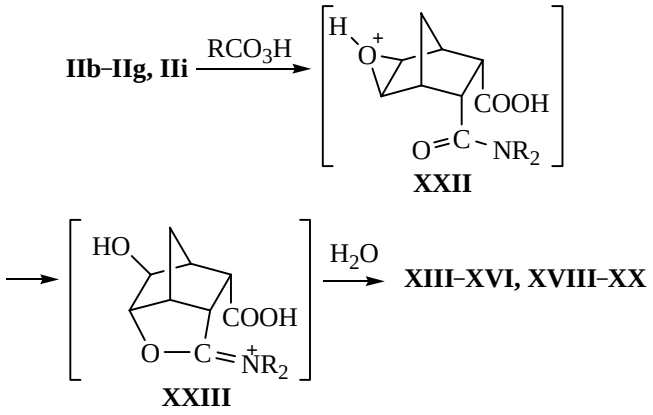
Analysis of ^{1}H NMR spectra was used for estimating the number and ratio of components in the oxidation products of amido acids of the norbornene series.

The ^{1}H NMR spectra contain signals characteristic of the products of intramolecular cyclization of compounds from the norbornene series: a singlet of *endo*-proton H^2 (4.00–5.50 ppm) and a doublet of *exo*-proton H^3 (4.25–4.70 ppm). The doublet appears because of coupling with a bridgehead proton H^7, whose signal is located in the region 3.12–3.30 ppm and looks as a complex multiplet owing to coupling with a large number of nuclei (H^8, H^6, H^3 etc.). The spectrum of every compound contains also two doublets from bridging protons (at 1.84–2.15 ppm for H^{8s} and 1.38–1.61 ppm for H^{8an}, $^2J_{8s,8an}$ 10.4–11.4 Hz) and two signals of *exo*-protons at C^6 and C^9 atoms (2.55–2.80 and 2.87–3.09 ppm respectively, $^3J_{6,9}$ 10.4–11.4 Hz), whereas the doublet of each of them is additionally split by coupling with protons H^1 and H^7. The resonances in the region 1.20–3.68 ppm belong to protons from the substituents attached to the amide nitrogen.

As criteria for assignment to the oxidation products of an amidolactone structure or that of a lactonoacid **XVII** salt the following spectral features were exploited: proton signals at the "ammonium" nitrogen atom of salts (8.00–8.30 ppm) and the reciprocal position of protons H^2 and H^3 (singlet and doublet) unlike in the spectra of the alternative reaction products. In the spectra of amidolactones the singlets of protons H^2 are located downfield whereas in the spectra of lactonoacid **XVII** salt the more downfield signal belongs to the doublet of protons H^3. In this fashion we were able to assign signals in the complex ^{1}H NMR spectra and to establish the content of individual components in the mixtures of oxidation products of amido acids **IIa–IIe**.

Amidolactones **IX–XII** were formed as a result of a nucleophilic attack of the oxygen from the carboxy group on the nearest electrophilic carbon of the protonated epoxy intermediate **XXII**, and salts of lactonoacid originate from hydrolysis of iminium intermediate **XXIII**.

The prevailing formation of salt-like products on oxidizing compounds **IIc** and **IId** compared to compounds **IIb** and **IIe** (82, 95 and 50, 62% respectively) may be due to the relative stability of intermediate **XXIII** as compared to structure **XXII** caused by electron-donor effect of the methyl groups.



In the study of oxidation with performic acid of a large group of amido acids from the norbornene series including the rests of heterocyclic nonaromatic amides in the majority of cases mixtures of substances were obtained where prevailed the salts of lactonoacid *exo*-2-hydroxy-5-oxo-4-[4.2.1.0^{3,7}]nonane-9-carboxylic acid with amines contained in the amido groups of the amido acids .

EXPERIMENTAL

IR spectra were measured on spectrophotometers UR-20 and Paragon 500 FT-IR from samples pelletized with KBr. ^{1}H NMR spectra were registered on spectrometers Varian VXR (operating frequencies 200 and 300 MHz), Inova 400 (operating frequency 400 MHz),

and Gemini-400BB (operating frequency 400 MHz) from solutions of compounds in DMSO-d_6 and $CDCl_3$, internal reference TMS. ^{13}C NMR spectra were recorded on spectrometers Inova 400 and Gemini-400BB (operating frequency 100.57 MHz). Mass spectrum of compound **IIa** was measured on AMD Integra 402 instrument at ionizing electrons energy 70 eV. The monitoring of reactions progress and checking the purity of compounds synthesized was carried out by TLC on Silufol UV-254 plates using as eluents ethyl ether (A), ethyl ether–2-propanol, 1:1 (B), and 2-propanol (C), development in iodine vapor. Elemental analysis was performed on analyzer Carlo Erba.

Crystals of compound **XXI** monoclinic. $C_{13}H_{17}NO_5$. At –173°C *a* 6.080(2), *b* 16.849(3), *c* 11.481(2) Å, β 100.14(2)°, *V* 1157.8(4) Å^3, M_r 267.28, *Z* 4, space group $P2_1/n$, d_{calc} 1.551 g/cm^3, μ(MoK_α) 0.119 mm^{-1}, *F*(000) 580. Parameters of the unit cell and intensity of 5894 reflections (2635 independent, R_{int} 0.055) were measured on a diffractometer Xcalibur-3 (MoK_α radiation, CCD-detector, graphite monochromator, ω-scanning, $2\theta_{max}$ 55°).

The structure was solved by the direct method using software SHELXTL [28]. Hydrogen atoms positions were revealed from the difference synthesis of the electron density and were refined isotropically. The structure was refined by F^2 full-matrix least-mean-squares procedure in anisotropic approximation for nonhydrogen atoms till wR_2 0.136 by 2614 reflexions [R_1 0.056 by 1744 reflexions with $F > 4\sigma(F)$, *S* 0.950]. The crystallographic data, atom coordinates, and geometric parameters of the structure are deposited in the Cambridge Structural Database (structure no. 293682).

Reaction of bicyclo[2.2.1]-hept-5-ene-*endo,endo*-2,3-dicarboxylic anhydride (I) with cyclic amines. To 3.28 g (0.02 mol) of endic anhydride (**I**) in 20–25 ml of benzene was added at stirring 0.02 mol of an appropriate amine. The reaction mixture was stirred at room temperature till completion of the reaction (TLC monitoring), usually from 1 to 4 days. The precipitated crystals were filtered off, washed with benzene on the filter, and dried in air. The reaction products were additionally purified by recrystallization from benzene or 2-propanol. By this procedures were synthesized amido acids **IIa–IIc**, and **IIe–IIi**.

***endo*-3-(Tetrahydro-1*H*-pyrrolylcarbonyl)-bicyclo[2.2.1]hept-5-ene-*endo*-2-carboxylic acid (IIa)**. Yield 3.71 g (79%), mp 168–170°C, R_f 0.11 (A), 0.67 (C). IR spectrum, cm^{-1}: 3436, 3063, 1724, 1640, 1594, 1550, 1254, 1186, 707. ^1H NMR spectrum (200 MHz, DMSO-d_6), δ, ppm: 6.14 m (1H, H^6), 6.00 m (1H, H^5), 3.41 d.d (1H, H^2), 3.23 d.d (1H, H^3, $^3J_{2,3}$ 8.1, $^3J_{2,1}$ = $^3J_{3,4}$ = 3.3 Hz), 3.00 m (1H, H^1), 2.93 m (1H, H^4), 1.90–1.60 (8H$_{cycle}$), 1.31 d (1H, H^{7s}), 1.21 d (1H, H^{7an}, $^2J_{7s,7an}$ 8.2 Hz). ^{13}C NMR spectrum (100.57 MHz, DMSO-d_6), δ, ppm: 173.4 (C=O), 170.2 (C=O), 136.2 (C^6), 133.3 (C^5), 48.4 (C^2), 48.0 (C^7), 47.6 (C^3), 46.1 (C^1), 46.0 (C^4), 45.8, 45.5, 25.8, 24.0 (C$_{cycle}$). Found, %: C 66.35; H 7.21; N 6.01. $C_{13}H_{17}NO_3$. Calculated, %: C 66.38; H 7.23; N 5.96.

***endo*-3-(piperidinocarbonyl)bicyclo[2.2.1]-hept-5-ene-*endo*-2-carboxylic acid (IIb)**. Yield 4.94 g (99%), mp 133–135°C, R_f 0.59 (A). IR spectrum, cm^{-1}: 3445, 3070, 1735, 1640, 1570, 1260, 1175, 725. ^1H NMR spectrum (400 MHz, DMSO-d_6), δ, ppm: 6.08 m (2H, H^5, H^6), 3.14 m (2H, H^2, H^3), 3.00, 1.64, 1.56 (10H$_{cycle}$), 2.98 m (2H, H^1, H^4), 1.24 d (1H, H^{7s}), 1.14 d (1H, H^{7an}, $^2J_{7s,7an}$ 8.0 Hz). ^{13}C NMR spectrum (100.57 MHz, DMSO-d_6), δ, ppm: 176.3 (C=O), 136.1 (C^5, C^6), 49.4 (C^2, C^3), 49.1 (C^1, C^4), 47.3 (C^7), 44.5, 23.1, 22.6 (C$_{cycle}$). Found, %: C 67.49; H 7.60; N 5.65. $C_{14}H_{19}NO_3$. Calculated, %: C 67.47; H 7.63; N 5.62.

***endo*-3-(2,6-Dimethylpiperidinocarbonyl)-bicyclo[2.2.1]hept-5-ene-*endo*-2-carboxylic acid (IIc)**. Yield 4.28 g (77%), mp 116–118°C, R_f 0.19 (A) R_f 0.39 (B). IR spectrum, cm^{-1}: 3430, 3065, 1720, 1635, 1560, 1270, 1180, 730. ^1H NMR spectrum (400 MHz, DMSO-d_6), δ, ppm: 6.03 m (2H, H^5, H^6), 3.10 m (2H, H^2, H^3), 3.03–2.96, 1.74–1.66, 1.46–1.36 (8H$_{cycle}$), 2.94 m (2H, H^1, H^4), 1.27 d (1H, H^{7s}), 1.19 d (1H, H^{7an}, $^2J_{7s,7an}$ 8.0 Hz), 1.15 s (3H, CH_3), 1.14 s (3H, CH_3). ^{13}C NMR spectrum (100.57 MHz, DMSO-d_6), δ, ppm: 176.2 (C=O), 136.1 (C^5, C^6), 53.0, 23.0, 20.0 (C$_{cycle}$), 49.4 (C^2, C^3), 49.1 (C^1, C^4), 47.3 (C^7), 30.7 (CH_3). Found, %: C 69.21; H 8.36; N 5.11. $C_{16}H_{23}NO_3$. Calculated, %: C 69.31; H 8.30; N 5.05.

***endo*-3-(1-Azepanylcarbonyl)bicyclo[2.2.1]hept-5-ene-*endo*-2-carboxylic acid (IIe)**. Yield 4.38 g (83%), mp 109–111°C, R_f 0 (at start) (A), 0.32 (B). IR spectrum, cm^{-1}: 3440, 3075, 1730, 1620, 1550, 1275, 1185, 715. ^1H NMR spectrum (300 MHz, DMSO-d_6), δ, ppm: 6.08 m (2H, H^5, H^6), 3.11 m (2H, H^2, H^3), 3.05, 1.73, 1.58 (12H$_{cycle}$), 3.03 m (2H, H^1, H^4), 1.24 d (1H, H^{7s}), 1.15 d (1H, H^{7an}, $^2J_{7s,7an}$ 8.0 Hz). Found, %: C 68.39; H 8.01; N 5.29. $C_{15}H_{21}NO_3$. Calculated, %: C 68.44; H 7.98; N 5.32.

***endo*-3-(Morpholinocarbonyl)bicyclo[2.2.1]-hept-5-ene-*endo*-2-carboxylic acid (IIf).** Yield 4.65 g (93%),

mp 148–150°C, R_f 0.69 (C). IR spectrum, cm^{-1}: 3430, 3060, 1730, 1635, 1560, 1280, 1190, 715. ^{1}H NMR spectrum (400 MHz, DMSO-d_6), δ, ppm: 6.30 m (1H, H^6), 5.92 m (1H, H^5), 3.60–3.55 (8H$_{cycle}$), 3.48 m (2H, H^2, H^3), 3.11 m (1H, H^1), 2.92 m (1H, H^4), 1.31 m (2H, H^{7s}, H^{7an}). Found, %: C 62.18; H 6.82; N 5.54. $C_{13}H_{17}NO_4$. Calculated, %: C 62.15; H 6.77; N 5.58.

***endo*-3-[4-(2-Hydroxyethyl)piperazinocarbonyl]bicyclo[2.2.1]hept-5-ene-*endo*-2-carboxylic acid (IIg)**. Yield 4.94 g (84%), mp 187–189°C, R_f 0.02 (C). IR spectrum, cm^{-1}: 3460, 3275, 3075, 1665, 1430, 1265, 725. ^{1}H NMR spectrum (400 MHz, DMSO-d_6), δ, ppm: 6.26 d.d (1H, H^6), 5.91 d.d (1H, H^5, $^3J_{5,6}$ 5.4, $^3J_{6,1}$ = $^3J_{5,4}$ = 2.7 Hz), 4.25 br.s (1H, OH), 3.65 m (1H, H^2), 3.60 m (1H, H^3), 3.50 t (2H, CH_2), 3.25 m (2H, H^1, H^4), 3.10–2.95, 2.60–2.20 (8H$_{cycle}$), 2.45 t (2H, CH_2), 1.30 m (2H, H^{7s}, H^{7an}). Found, %: C 61.18; H 7.39; N 9.41. $C_{15}H_{22}N_2O_4$. Calculated, %: C 61.22; H 7.48; N 9.52.

***endo*-3-(1,5-Dimethyl-3-oxo-2-phenyl-2,3-dihydro-1*H*-4-pyrazolylcarbamoyl)bicyclo[2.2.1]hept-5-ene-*endo*-2-carboxylic acid (IIh)**. Yield 6.28 g (86%), mp 228–230°C, R_f 0.52 (C). IR spectrum, cm^{-1}: 3480, 3060, 1745, 1620, 1260, 1159, 708. ^{1}H NMR spectrum (400 MHz, $CDCl_3$), δ, ppm: 8.76 br.s (1H, NH), 7.43–7.24 (5H$_{arom}$), 6.37 d.d (1H, H^6), 6.15 d.d (1H, H^5, $^3J_{6,1}$ = $^3J_{5,4}$ = 2.8 Hz), 3.48 d.d (1H, H^2), 3.35 d.d (1H, H^3, $^3J_{2,3}$ 9.6, $^3J_{3,4}$ 3.2 Hz), 3.10 m (1H, H^1), 3.03 C (3H, CH_3), 3.01 m (1H, H^4), 2.04 s (3H, CH_3), 1.39 d (1H, H^{7s}), 1.28 d (1H, H^{7an}, $^2J_{7s,7an}$ 8.4 Hz). ^{13}C NMR spectrum (100.57 MHz, $CDCl_3$), δ, ppm: 175.6 (C=O), 172.9 (C=O), 161.9 (C=O), 136.6 (C^6), 135.6 (C^5), 135.2–127.6 (C$_{arom}$), 49.0 (C^2), 48.9 (C^7), 48.1 (C^3), 46.3 (C^1), 46.0 (C^4), 45.5, 45.0 (C$_{cycle}$), 35.6 (CH_3), 11.7 (CH_3). Found, %: C 65.43; H 5.76; N 11.39. $C_{20}H_{21}N_3O_4$. Calculated, %: C 65.40; H 5.72; N 11.44.

***N*,*N*'-{Di(*endo*-2-carboxybicyclo[2.2.1]hept-5-ene-*endo*-3-carbonyl)}piperazine (IIi)** was prepared from 0.02 mol of anhydride **I** and 0.01 mol of piperazine. Yield 5.52 g (67%), mp 214–216°C (decomp.), R_f 0.75 (C). IR spectrum, cm^{-1}: 3428, 3076, 1728, 1620, 1574, 1254, 1224, 1174, 720. ^{1}H NMR spectrum (300 MHz, DMSO-d_6), δ, ppm: 6.27 m (2H, H^6), 5.92 m (2H, H^5), 3.37 m (2H, H^2), 3.33 m (2H, H^3), 3.68–3.65, 2.91–2.89 (8H$_{cycle}$), 3.07 m (4H, H^1, H^4), 1.34 d (2H, H^{7s}), 1.30 d (2H, H^{7an}, $^2J_{7s,7an}$ 8.1 Hz). Found, %: C 63.71; H 6.33; N 6.81. $C_{22}H_{26}N_2O_6$. Calculated, %: C 63.77; H 6.28; N 6.76.

***endo*-3-(2,2,6,6-Tetramethyl-1-piperidinocarbonyl)bicyclo[2.2.1]hept-5-ene-*endo*-2-carboxylic acid (IId)**. To 3.28 g (0.02 mol) of endic anhydride (**I**) in 25 ml of anhydrous benzene was added 2.82 g (0.02 mol) of 2,2,6,6-tetramethylpiperidine, and the mixture was boiled for 7 h (TLC monitoring). On cooling the precipitated crystals were filtered off, washed with benzene on the filter, dried in air, and purified by recrystallization from a mixture benzene–2-propanol, 1:1. Yield 4.12 g (68%), mp 124–126°C, R_f 0.12 (B), 0.20 (C). IR spectrum, cm^{-1}: 3430, 3054, 1728, 1622, 1578, 1272, 1184, 732. ^{1}H NMR spectrum (200 MHz, DMSO-d_6), δ, ppm: 6.26 m (1H, H^6), 6.07 m (1H, H^5), 3.72 m (1H, H^2), 3.34 m (1H, H^3), 3.12 m (1H, H^1), 3.00 m (1H, H^4), 1.65–1.53 (6H, 3CH_2), 1.33 (12H, 4CH_3), 1.24 d (1H, H^{7s}), 1.14 d (1H, H^{7an}, $^2J_{7s,7an}$ 8.0 Hz). Found, %: C 70.73; H 8.81; N 4.63. $C_{18}H_{27}NO_3$. Calculated, %: C 70.82; H 8.85; N 4.59.

***N*-(1,5-Dimethyl-3-oxo-2-phenyl-2,3-dihydro-1*H*-4-pyrazolyl)bicyclo[2.2.1]hept-5-ene-*endo*,*endo*-2,3-dicarboximide (IV)**. To 15 ml of glacial acetic acid was added 0.73 g (2 mmol) of amido acid **IIh**, and the mixture obtained was boiled till completion of reaction (TLC monitoring). The acetic acid was distilled off in a vacuum, to the solid residue 7 ml of ice water was added, the separated crystals were filtered off, dried, and recrystallized from 2-propanol. Yield 0.51 g (74%), mp 232.5–234°C, R_f 0 (at start) (A), 0.28 (B), 0.43 (C). IR spectrum, cm^{-1}: 3060, 1758, 1705, 1662, 1588, 1487, 1185, 848, 715. ^{1}H NMR spectrum (300 MHz, DMSO-d_6), δ, ppm: 7.39–7.31 (5H$_{arom}$), 6.26 m (2H, H^5, H^6), 3.57 m (1H, H^1), 3.51 m (1H, H^4), 3.43 m (2H, H^2, H^3), 3.15 s (3H, CH_3), 2.08 s (3H, CH_3), 1.61 m (2H, H^{7s}, H^{7an}). Found, %: C 68.71; H 5.50; N 12.11. $C_{20}H_{19}N_3O_3$. Calculated, %: C 68.77; H 5.44; N 12.03.

***N*-(1,5-Dimethyl-3-oxo-2-phenyl-2,3-dihydro-1*H*-4-pyrazolyl)-*exo*-5,6-epoxybicyclo[2.2.1]heptane-*endo*,*endo*-2,3-dicarboxamide (V)**. To 0.70 g (2 mmol) of compound **IV** in 6–7 ml of 98% formic acid was added dropwise at stirring 0.23 ml (4 mmol) of 50% water solution of hydrogen peroxide, and the stirring was continued at room temperature till the end of the reaction (TLC monitoring). The volatile substances were removed in a vacuum, to the solid residue 5–7 ml of ice water was added, the separated crystals were filtered off, dried, and recrystallized from 2-propanol. Yield 0.49 g (67%), mp 243–245°C, R_f 0 (at start) (A), R_f 0.32 (C). IR spectrum, cm^{-1}: 3030, 1735, 1685, 1615, 1510, 1400, 1188, 858. ^{1}H NMR spectrum (300 MHz, DMSO-d_6), δ, ppm: 7.55–

7.48 ($5H_{arom}$), 3.36 m (1H, H^5), 3.31 m (1H, H^6), 3.19 s (3H, CH_3), 2.96 m (2H, H^2, H^3), 2.91 m (2H, H^1, H^4), 2.17 s (3H, CH_3), 1.37 d (1H, H^{7s}), 1.10 d (1H, H^{7an}, $^2J_{7s,7an}$ 10.2 Hz). Found, %: C 65.71; H 5.30; N 11.46. $C_{20}H_{19}N_3O_4$. Calculated, %: C 65.75; H 5.21; N 11.51.

Oxidation of amido acids of norbornene series with performic acid in situ. To 2 mmol of an appropriate amido acid **IIb–IIg** and **IIi** in 5–8 ml of 98% formic acid was added dropwise at 0°C while stirring 0.23 ml (4 mmol) of 50% water solution of hydrogen peroxide, and the stirring was continued at this temperature till the end of the reaction (TLC monitoring). The formic acid was removed in a vacuum, to the oily residue was added ethyl ether, and after prolonged grinding in the cold the formed crystals were filtered off and dried.

Mixture of ***endo*-9-(piperidino)carbonyl-*exo*-2-hydroxy-4-oxatricyclo-[4.2.1.0^{3,7}]-nonan-5-one (IX)** (50%) and **piperidinium *exo*-2-hydroxy-5-oxo-4-oxatricyclo-[4.2.1.0^{3,7}]-nonane-*endo*-9-carboxylate (XIII)** (50%). Yield 0.42 g (76%). IR spectrum, cm^{-1}: 3400, 2555, 1770, 1625, 1595, 1400, 1355, 1170, 1030, 770. ^{1}H NMR spectrum (300 MHz, DMSO-d_6), δ, ppm (**IX**): 4.80 br.s (1H, OH), 4.75 C (1H, H^2), 4.70 d (1H, H^3, $^3J_{3,7}$ 5.1 Hz), 3.27 m (1H, H^7), 3.04 d.d (1H, H^9, $^3J_{6,9}$ 10.8 Hz), 2.61 d.d (1H, H^6, $^3J_{6,7}$ 4.5 Hz), 2.36 br.s (1H, H^1), 1.98 d (1H, H^{8s}), 1.64, 1.53 ($10H_{cycle}$), 1.53 d (1H, H^{8an}, $^2J_{8s,8an}$ 11.1 Hz); (**XIII**): 8.15 br.s (2H, H_2N^+), 4.25 d (1H, H^3, $^3J_{3,7}$ 5.7 Hz), 4.12 C (1H, H^2), 3.37 br.s (1H, OH), 3.12 m (1H, H^7), 2.87 d.d (1H, H^9, $^3J_{9,1}$ 3.9, $^3J_{6,9}$ 11.4 Hz), 2.55 d.d (1H, H^6, $^3J_{6,7}$ 5.4 Hz), 2.36 br.s (1H, H^1), 1.90 d (1H, H^{8s}), 1.64, 1.53 ($10H_{cycle}$), 1.43 d (1H, H^{8an}, $^2J_{8s,8an}$ 10.8 Hz).

Mixture of ***endo*-9-(2,6-dimethyl-1-piperidino)-carbonyl-*exo*-2-hydroxy-4-oxatricyclo[4.2.1.0^{3,7}]-nonan-5-one (X)** (18%) and **2,6-dimethylpiperidinium *exo*-2-hydroxy-5-oxo-4-oxatricyclo[4.2.1.0^{3,7}]-nonane-*endo*-9-carboxylate (XIV)** (82%). Yield 0.48 g (81%). IR spectrum, cm^{-1}: 3355, 2570, 1770, 1620, 1590, 1390, 1355, 1170, 1025, 770. ^{1}H NMR spectrum (200 MHz, DMSO-d_6), δ, ppm (**X**): 5.33 C (1H, H^2), 5.10 br.s (1H, OH), 4.54 d (1H, H^3, $^3J_{3,7}$ 5.0 Hz), 3.25 m (1H, H^7), 3.05 d.d (1H, H^9, $^3J_{9,1}$ 3.6, $^3J_{6,9}$ 10.4 Hz), 2.68 d.d (1H, H^6, $^3J_{6,7}$ 4.4 Hz), 2.39 br.s (1H, H^1), 1.84 d (1H, H^{8s}), 1.77–1.65 (6H, $3CH_2$), 1.38 d (1H, H^{8an}, $^2J_{8s,8an}$ 11.0 Hz), 1.36–1.33 (2H, 2CH), 1.20 (6H, $2CH_3$); (**XIV**): 8.30 br.s (2H, H_2N^+), 5.10 br.s (1H, OH), 4.28 d (1H, H^3, $^3J_{3,7}$ 4.8 Hz), 4.04 s (1H, H^2), 3.16 m (1H, H^7), 2.97 d.d (1H, H^9, $^3J_{9,1}$ 3.6, $^3J_{6,9}$ 11.2 Hz), 2.60 d.d (1H, H^6, $^3J_{6,7}$ 4.5 Hz), 2.39 br.s (1H, H^1), 1.93 d (1H, H^{8s}), 1.77–1.65 (6H, $3CH_2$), 1.47 d (1H, H^{8an}, $^2J_{8s,8an}$ 11.0 Hz), 1.36–1.33 (2H, 2CH), 1.20 (6H, $2CH_3$).

Mixture of ***endo*-9-(2,2,6,6-tetramethyl-1-piperidino)carbonyl-*exo*-2-hydroxy-4-oxatricyclo[4.2.1.0^{3,7}]nonan-5-one (XI)** (5%) and **2,2,6,6-tetramethylpiperidinium *exo*-2-hydroxy-5-oxo-4-oxatricyclo-[4.2.1.0^{3,7}]-nonane-*endo*-9-carboxylate (XV)** (95%). Yield 0.56 g (86%). IR spectrum, cm^{-1}: 3435, 2620, 2480, 1775, 1635, 1595, 1395, 1360, 1175, 1025, 770. ^{1}H NMR spectrum (200 MHz, DMSO-d_6), δ, ppm (**XI**): 5.28 s (1H, H^2), 5.10 br.s (1H, OH), 4.56 d (1H, H^3, $^3J_{3,7}$ 4.8 Hz), 3.28 m (1H, H^7), 3.07 d.d (1H, H^9, $^3J_{9,1}$ 3.0, $^3J_{6,9}$ 10.6 Hz), 2.73 d.d (1H, H^6, $^3J_{6,7}$ 4.2 Hz), 2.39 br.s (1H, H^1), 1.86 d (1H, H^{8s}), 1.66–1.51 ($6H_{cycle}$), 1.45 d (1H, H^{8an}, $^2J_{8s,8an}$ 10.4 Hz), 1.33 (12H, $4CH_3$); (**XV**): 8.24 br.s (2H, H_2N^+), 5.10 br.s (1H, OH), 4.29 d (1H, H^3, $^3J_{3,7}$ 5.6 Hz), 4.02 s (1H, H^2), 3.17 m (1H, H^7), 3.00 d.d (1H, H^9, $^3J_{9,1}$ 3.3, $^3J_{6,9}$ 10.9 Hz), 2.62 d.d (1H, H^6, $^3J_{6,7}$ 5.0 Hz), 2.39 br.s (1H, H^1), 1.94 d (1H, H^{8s}), 1.66–1.51 ($6H_{cycle}$), 1.48 d (1H, H^{8an}, $^2J_{8s,8an}$ 10.4 Hz), 1.33 (12H, $4CH_3$).

Mixture of ***endo*-9-(1-azepanyl)carbonyl-*exo*-2-hydroxy-4-oxatricyclo-[4.2.1.0^{3,7}]-nonan-5-one (XII)** (38%) and **azepanium *exo*-2-hydroxy-5-oxo-4-oxatricyclo-[4.2.1.0^{3,7}]-nonane-*endo*-9-carboxylate (XVI)** (62%). Yield 0.21 g (36%). IR spectrum, cm^{-1}: 3600, 3460, 2600, 1790, 1740, 1640, 1415, 1355, 1200, 1180, 1030, 770. ^{1}H NMR spectrum (300 MHz, $CDCl_3$), δ, ppm (**XII**): 6.49 br.s (1H, OH), 5.50 C (1H, H^2), 4.57 d (1H, H^3, $^3J_{3,7}$ 5.1 Hz), 3.30 m (1H, H^7), 3.09 d.d (1H, H^9, $^3J_{9,1}$ 3.8, $^3J_{6,9}$ 10.7 Hz), 2.80 d.d (1H, H^6, $^3J_{6,7}$ 3.8 Hz), 2.15 d (1H, H^{8s}), 2.02 br.s (1H, H^1), 1.88, 1.72–1.68 ($12H_{cycle}$), 1.59 d (1H, H^{8an}, $^2J_{8s,8an}$ 11.3 Hz); (**XVI**): 8.03 br.s (2H, H_2N^+), 6.49 br.s (1H, OH), 4.50 d (1H, H^3, $^3J_{3,7}$ 5.1 Hz), 4.29 C (1H, H^2), 3.22 m (1H, H^7), 3.05 d.d (1H, H^9, $^3J_{9,1}$ 3.0, $^3J_{6,9}$ 10.8 Hz), 2.70 d.d (1H, H^6, $^3J_{6,7}$ 4.1 Hz), 2.06 br.s (1H, H^1), 1.88, 1.72–1.68 ($12H_{cycle}$). ^{1}H NMR spectrum (300 MHz, DMSO-d_6) (XII): 6.70 br.s (1H, OH), 5.37 C (1H, H^2), 4.53 d (1H, H^3, $^3J_{3,7}$ 4.8 Hz), 3.24 m (1H, H^7), 1.78–1.68, 1.60–1.56 ($12H_{cycle}$), 3.00 d.d (1H, H^9, $^3J_{6,9}$ 10.5 Hz), 2.66 d.d (1H, H^6, $^3J_{6,7}$ 4.2 Hz), 2.38 br.s (1H, H^1), 1.84 d (1H, H^{8s}), 1.61 d (1H, H^{8an}, $^2J_{8s,8an}$ 11.1 Hz); (XVI): 8.20 br.s (2H, H_2N^+), 6.70 br.s (1H, OH), 4.27 d (1H, H^3, $^3J_{3,7}$ 5.1 Hz), 4.07 C (1H, H^2), 3.15 m (1H, H^7), 2.95 d.d (1H, H^9, $^3J_{9,1}$ 3.3, $^3J_{6,9}$ 10.5 Hz), 2.59 d.d (1H, H^6, $^3J_{6,7}$ 4.2 Hz), 2.38 br.s (1H, H^1), 1.92 d (1H, H^{8s}), 1.78–1.68, 1.60–1.56 ($12H_{cycle}$), 1.46 d (1H, H^{8an}, $^2J_{8s,8an}$ 10.5 Hz).

Morpholinium *exo*-2-hydroxy-5-oxo-4-oxatricyclo[4.2.1.0^{3,7}]-nonane-*endo*-9-carboxylate (XVIII). Yield 0.45 g (80%), mp 174–177°C. IR spectrum, cm^{-1}: 3410, 2530, 1785, 1595, 1410, 1360, 1170, 1120, 1025, 765. ^{1}H NMR spectrum (200 MHz, DMSO-d_6), δ, ppm: 8.02 br.s (2H, H_2N^+), 4.29 d (1H, H^3, $^3J_{3,7}$ 5.0 Hz), 4.05 s (1H, H^2), 3.70 br.s (1H, OH), 3.60–3.50, 3.40–3.34 (8H$_{cycle}$), 3.16 m (1H, H^7), 2.98 d.d (1H, H^9, $^3J_{9,1}$ 3.5, $^3J_{6,9}$ 10.7 Hz), 2.61 d.d (1H, H^6, $^3J_{6,7}$ 4.5 Hz), 2.39 br.s (1H, H^1), 1.93 d (1H, H^{8s}), 1.48 d (1H, H^{8an}, $^2J_{8s,8an}$ 10.7 Hz). Found, %: C 54.69; H 6.60; N 4.96. $C_{13}H_{19}NO_6$. Calculated, %: C 54.74; H 6.67; N 4.91.

1-(2-Hydroxyethyl)-4-piperazinium *exo*-2-hydroxy-5-oxo-4-oxatricyclo[4.2.1.0^{3,7}]nonane-*endo*-9-carboxylate (XIX). Yield 0.52 g (79%), oily substance. IR spectrum, cm^{-1}: 3400, 2645, 1787, 1732, 1605, 1415, 1365, 1215, 1185, 1030, 775. ^{1}H NMR spectrum (300 MHz, DMSO-d_6), δ, ppm: 8.02 br.s (2H, H_2N^+), 4.30 d (1H, H^3, $^3J_{3,7}$ 4.5 Hz), 4.03 s (1H, H^2), 3.51 t (2H, CH_2), 3.36, 2.41 (8H$_{cycle}$), 3.18 m (1H, H^7), 3.01 d.d (1H, H^9, $^3J_{9,1}$ 2.7, $^3J_{6,9}$ 10.5 Hz), 2.64 d.d (1H, H^6, $^3J_{6,7}$ 4.2 Hz), 2.43 br.s (1H, H^1), 2.35 t (2H, CH_2), 1.94 d (1H, H^{8s}), 1.50 d (1H, H^{8an}, $^2J_{8s,8an}$ 10.5 Hz). Found, %: C 54.83; H 7.39; N 8.63. $C_{15}H_{24}N_2O_6$. Calculated, %: C 54.88; H 7.32; N 8.54.

Piperazinium *exo*-2-hydroxy-5-oxo-4-oxatricyclo[4.2.1.0^{3,7}]nonane-*endo*-9-carboxylate (XX) was obtained by treating with 8 mmol of oxidant 2 mmol of amide **IIi**. Yield 0.34 g (59%), mp 170–172°C. IR spectrum, cm^{-1}: 3400, 2606, 1782, 1632, 1414, 1348, 1202, 1178, 1014, 760. ^{1}H NMR spectrum (200 MHz, DMSO-d_6), δ, ppm: 8.21 br.s (2H, H_2N^+), 8.00 br.s (2H, H_2N^+), 5.25 br.s (2H, OH), 4.27 d (2H, H^3, $^3J_{3,7}$ 4.8 Hz), 4.00 s (2H, H^2), 3.54–3.50, 3.40–3.30 (8H$_{cycle}$), 3.15 m (2H, H^7), 2.98 d.d (2H, H^9, $^3J_{9,1}$ 3.6, $^3J_{6,9}$ 11.0 Hz), 2.61 d.d (2H, H^6, $^3J_{6,7}$ 4.6 Hz), 2.38 br.s (2H, H^1), 1.92 d (2H, H^{8s}), 1.47 d (2H, H^{8an}, $^2J_{8s,8an}$ 10.7 Hz). Found, %: C 54.83; H 6.19; N 5.83. $C_{22}H_{30}N_2O_{10}$. Calculated, %: C 54.77; H 6.22; N 5.81.

Azepanium *exo*-2-hydroxy-5-oxo-4-oxatricyclo[4.2.1.0^{3,7}]-nonane-*endo*-9-carboxylate (XVI). To 0.53 g (2 mmol) of compound **IIe** in 8 ml of glacial acetic acid was added dropwise while stirring at room temperature 0.23 ml (4 mmol) of 50% water solution of hydrogen peroxide, and the stirring was continued at this temperature for 10 days till the end of the reaction (TLC monitoring). The acetic acid was removed in a vacuum, to the oily residue was added ethyl ether, and after prolonged grinding in the cold the formed crystals were filtered off and dried. Yield 0.42 g (71%), mp 151–153°C. IR spectrum, cm^{-1}: 3470, 2600, 1795, 1725, 1610, 1420, 1370, 1170, 1030, 770. ^{1}H NMR spectrum (300 MHz, DMSO-d_6), δ, ppm: 8.00 br.s (2H, H_2N^+), 4.27 d (1H, H^3, $^3J_{3,7}$ 5.1 Hz), 4.08 s (1H, H^2), 3.15 m (1H, H^7), 2.93 d.d (1H, H^9, $^3J_{9,1}$ 3.2, $^3J_{6,9}$ 10.7 Hz), 2.58 d.d (1H, H^6, $^3J_{6,7}$ 4.4 Hz), 2.38 br.s (1H, H^1), 1.92 d (1H, H^{8s}), 1.73, 1.58 (12H$_{cycle}$), 1.46 d (1H, H^{8an}, $^2J_{8s,8an}$ 11.4 Hz). Found, %: C 60.69; H 7.80; N 4.63. $C_{15}H_{23}NO_5$. Calculated, %: C 60.61; H 7.74; N 4.71.

Substituted *endo*-9-carbamoyl-*exo*-2-hydroxy-4-oxatricyclo[4.2.1.0^{3,7}]nonan-5-ones XII and XXI. To 2 mmol of salt **XVI** or **XVIII** in 10–12 ml of anhydrous dichloromethane was added at room temperature while stirring a solution of 0.41 g (2 mmol) of dicyclohexylcarbodiimide in 5 ml of anhydrous dichloromethane. After stirring for 4–7 days the precipitate was filtered off and washed on the filter with dichloromethane. The filtrate was evaporated in a vacuum, the solid residue was ground under a layer of ethyl ether, the reaction product was filtered off, washed with ether, and dried in air. The solid dicyclohexylurea was stirred with 12–15 ml of water for 40 min at 40–45°C, insoluble in water dicyclohexylurea was filtered off and washed with water. The water filtrate was evaporated till solid residue was obtained. Both portions of the product were combined and thrice recrystallized from 2-propanola (or acetone).

***endo*-9-1-Azepanylcarbonyl-*exo*-2-hydroxy-4-oxatricyclo[4.2.1.0^{3,7}]nonan-5-one (XII).** Yield 0.41 g (73%), mp 230–231°C, R_f 0.65 (C). IR spectrum, cm^{-1}: 3395, 1805, 1625, 1465, 1165, 1025. ^{1}H NMR spectrum (300 MHz, DMSO-d_6), δ, ppm: 5.07 s (1H, H^2), 4.43 m (1H, H^3), 4.30 br.s (1H, OH), 3.27 m (1H, H^9), 3.23 m (1H, H^7), 2.69 m (1H, H^6), 2.31 br.s (1H, H^1), 1.97 d (1H, H^{8s}), 1.70, 1.52 (12H$_{cycle}$), 1.50 d (1H, H^{8an}, $^2J_{8s,8an}$ 11.1 Hz). Found, %: C 64.60; H 7.49; N 4.99. $C_{15}H_{21}NO_4$. Calculated, %: C 64.52; H 7.53; N 5.02.

Compound **XII** was similarly obtained from 0.58 g (2 mmol) of a mixture of compounds obtained by oxidation of amide **IIe**, and 0.25 g (1.2 mmol) of dicyclohexylcarbodiimide. Yield 0.42 g (75%), mp 229–231°C, R_f 0.65 (C).

***endo*-9-Morpholinocarbonyl-*exo*-2-hydroxy-4-oxatricyclo[4.2.1.0^{3,7}]nonan-5-one (XXI).** Yield 0.43 g (80%), mp 205–208°C, R_f 0.33 (B). IR spectrum, cm^{-1}: 3420, 1795, 1630, 1460, 1130, 1080, 1015. ^{1}H NMR spectrum (300 MHz, DMSO-d_6), δ, ppm: 5.10 br.s (1H,

OH), 4.39 s (1H, H^2), 4.31 d (1H, H^3, $^3J_{3,7}$ 5.1 Hz), 3.73–3.66, 3.59–3.44, 3.41–3.34 ($8H_{cycle}$), 3.29 d.d (1H, H^9, $^3J_{9,1}$ 3.3, $^3J_{6,9}$ 9.4 Hz), 3.20 m (1H, H^7), 2.74 d.d (1H, H^6, $^3J_{6,7}$ 4.7 Hz), 2.33 br.s (1H, H^1), 1.97 d (1H, H^{8s}), 1.49 d (1H, H^{8an}, $^2J_{8s,8an}$ 10.2 Hz). Found, %: C 58.40; H 6.39; N 5.25. $C_{13}H_{17}NO_5$. Calculated, %: C 58.43; H 6.37; N 5.24.

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