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Synthesis of 4-Formyl-3-cyclopentene-1,1,2-tricarbonitriles

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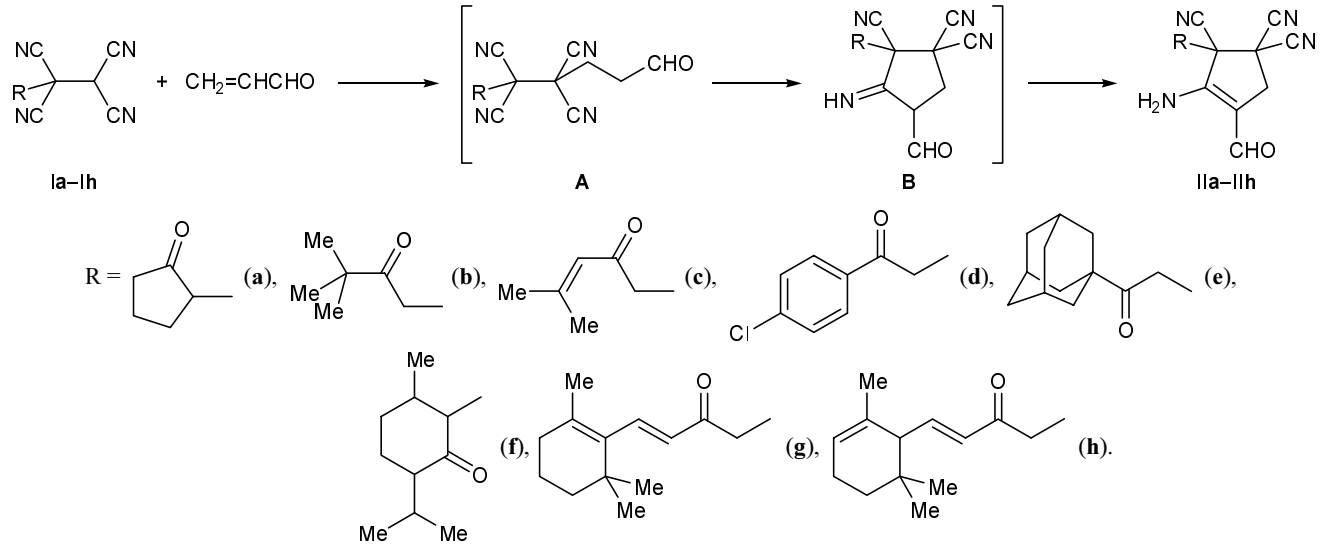
Abstract—β,β,γ,γ-Tetracyanoalkanones react with acrolein at a high rate to afford the corresponding 2-substituted 4-formyl-3-cyclopentene-1,1,2-tricarbonitriles in high yields. The reaction occurs under mild conditions and is quite applicable for modification of natural and biologically active compounds possessing an R'CHC(O)CR_3 fragment to obtain their derivatives containing three cyano groups.

The synthesis and properties of cyanocyclopentenes are subjects of regular studies performed by several research groups. These compounds are generally prepared by cycloaddition 1,1,2,2-tetracyanoethane to alkenes [1–3], various rearrangements of cyano-substituted cyclic compounds [4], and elimination of HCN from cyclopentanecarbonitriles [5–8]. Cyanation of biologically active compounds is important. Introduction of a cyano group gives rise to reactive biologically active compounds with different properties. For example, the properties of cyanopregnenolone or pregnenolone-16α-carbonitrile differ from those of its precursor; this compound acts as an inductor of liver monooxygenase system which metabolizes drugs [9].

Heating of ergosterol acetate with tetracyanoethylene in benzene gave 3β-acetoxy-7α-(1,1,2,2-tetracyanoethyl)ergosta-5,8(14),22-triene [10]. Substituted quinolines were subjected to cyanomethylation with a view to obtain new medical agents [11]. Analysis of published data on cyanation of biologically active compounds [9–12] and methods of synthesis of cyano-substituted cyclopentenes [1–8] shows that the corresponding reactions take from 1 h to several days on heating and the yields are on the average 30–50%.

We have developed a new procedure for the transformation of ketones (including naturally occurring and biologically active) into 4-formyl-3-cyclopentene-1,1,2-tricarbonitrile derivatives. The procedure is based

Scheme 1.



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on tetracyanoethylation of initial ketones, followed by conversion of β,β,γ,γ-tetracyanoalkanones thus formed into substituted cyclopentenes. Milddenton *et al*. [13] previously synthesized a large number of β,β,γ,γ-tetracyanoalkanones in the presence of "molecular silver" as catalyst; the product yields ranged from 50 to 94%. We improved this procedure using alcohols (MeOH, EtOH) and acids as catalysts (yield 76–92%) [15]. While studying the properties of β,β,γ,γ-tetracyanoalkanones **I** we found that these compounds are highly reactive [14]: they undergo gradual decomposition on storage at room temperature. Tetracyanoalkanones were converted into more stable cyano derivatives via reaction with acrolein. The reaction was regioselective,

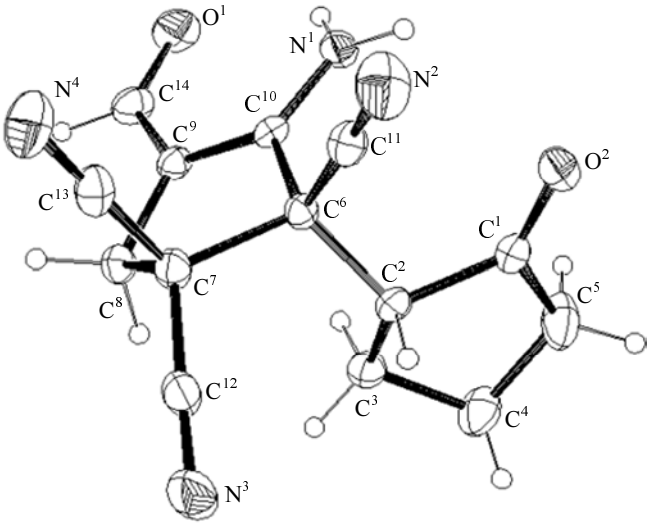


Fig. 1. Structure of the molecule of 3-amino-4-formyl-2-(2-oxocyclopentyl)-3-cyclopentene-1,1,2-tricarbonitrile (**IIa**) according to the X-ray diffraction data.

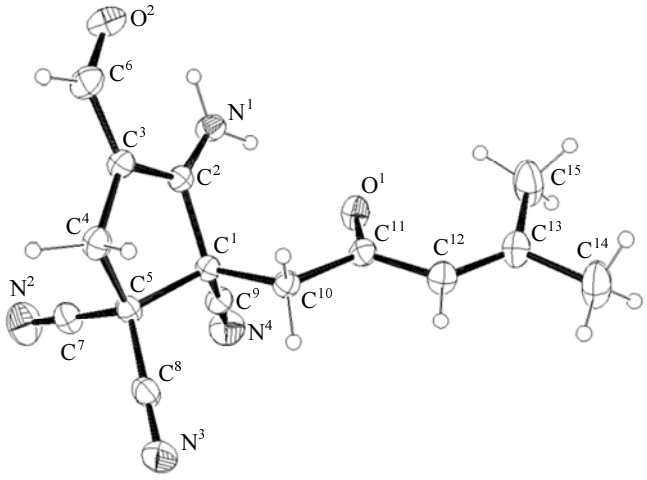


Fig. 2. Structure of the molecule of 3-amino-4-formyl-2-(4-methyl-2-oxo-3-pentenyl)-3-cyclopentene-1,1,2-tricarbonitrile (**IIc**) according to the X-ray diffraction data.

and the double C=C and C=O bonds in initial compounds **I** were not involved. Cyclopentene derivatives **II** thus obtained (Scheme 1) possess a variety of functional groups and are promising as synthons. According to the TLC data, the transformation of compounds **Ia**–**Ih** into cyclopentene derivatives **IIa**–**IIh** is complete in 20–30 min at room temperature, and the yields of the final products are 65–92%.

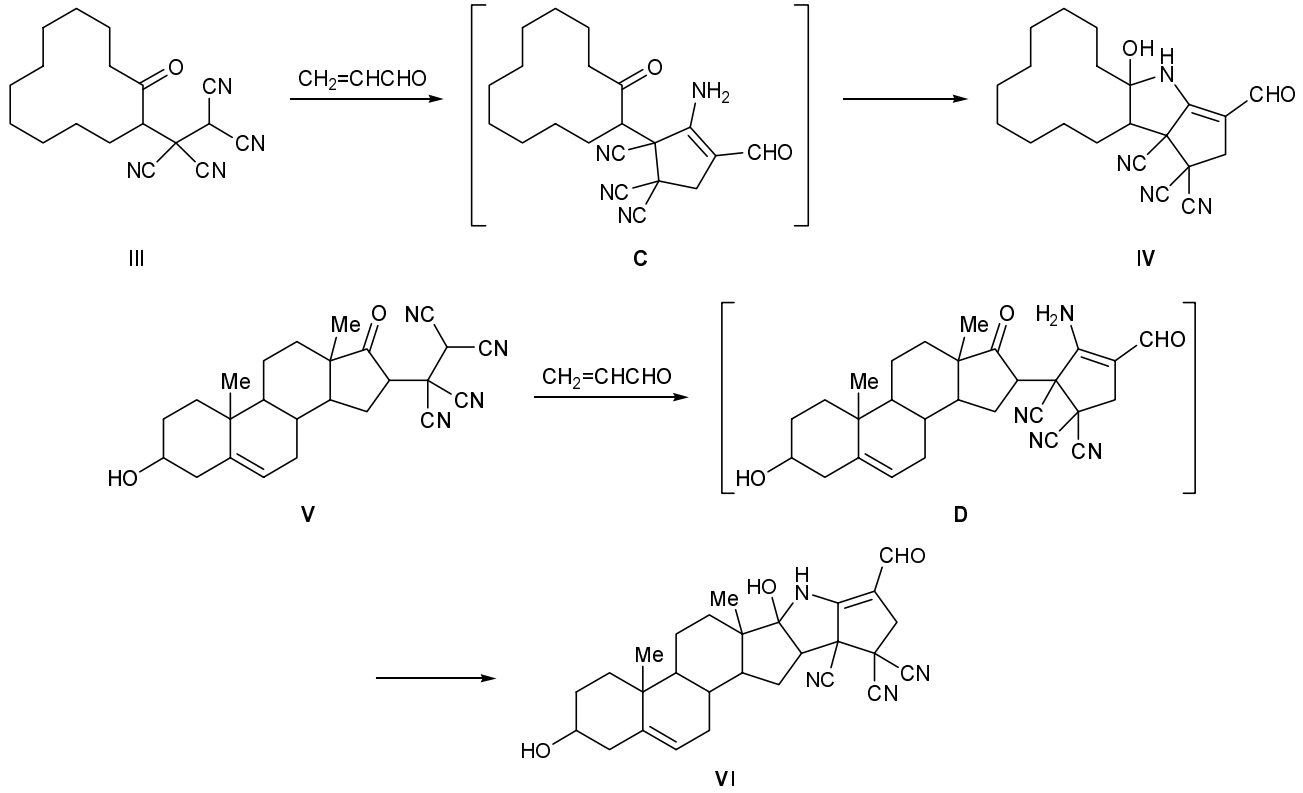
Initial tetracyanoalkanones **Ia**–**Ih** were prepared by the known method from the corresponding ketone (cyclopentanone, pinacolone, 4-methyl-3-penten-2-one, 4-chloroacetophenone, 1-acetyladamantane, β-ionone, and α-ionone) and tetracyanoethylene in dioxane in the presence of 2–3 drops of concentrated hydrochloric acid as catalyst.

Presumably, β,β,γ,γ-tetracyanoalkanones **Ia**–**Ih** react with acrolein to give intermediates **A** which undergo intramolecular cyclization into iminocyclopentanes **B**, and isomerization of the latter leads to final products, compounds **IIa**–**IIh**. The structure of products **IIa**–**IIh** was proved by X-ray analysis and ^{1}H NMR, IR, and mass spectra.

In order to isolate compounds **IIa**–**IIh** in the crystalline state, the reaction mixtures were kept for 12–24 h at room temperature. As a result, we obtained single crystals suitable for X-ray analysis. The structures of molecules **IIa** and **IIc** with atom numbering are shown in Figs. 1 and 2. According to the X-ray diffraction data, the amino group in their molecules is involved in intramolecular hydrogen bonds, primarily with the carbonyl oxygen atom of the formyl group. The distance $N^1H\cdots O^1$ in molecule **IIa** is 2.14(2) Å, and the angle N^1HO^1 is 127(2)°. The corresponding parameters for molecule **IIc** are almost similar: $H^2\cdots O^2$ 2.12(2) Å, $\angle N^1H^2O^2$ 128(2)°. The formation of that hydrogen bond ensures planar structure of the fragment including the atoms contiguous to the double bond between the formyl and amino groups. Deviations of these atoms from the mean-square plane do not exceed 0.020(1) Å, while the C^7 atom in molecule **IIa** or C^5 in **IIc** (Figs. 1, 2) deviates from that plane by 0.520(2) and 0.581(3) Å, respectively. Thus the five-membered rings C^6–C^{10} (**IIa**) and C^1–C^5 (**IIc**) adopt conformations of C^7- and C^5-*envelope*, respectively. An analogous C^3-*envelope* conformation is inherent to the second five-membered ring in molecule **IIa**, which includes C^1–C^5 atoms.

On the other hand, intramolecular hydrogen bond between the formyl and amino groups enhances *n*–π conjugation in the amino group–double bond–carbonyl

Scheme 2.



group sequence. This is reflected in shortening of the N^1–C^{10} and C^9–C^4 bonds [1.324(2) and 1.428(2) Å, respectively] and extension of the double C^{10}=C^9 and C^{14}=O^1 bonds [1.364(2) and 1.226(1) Å, respectively], as compared to the corresponding bonds in the absence of conjugation [21]. Similar bond lengths (within experimental error) are also typical of molecule **IIc**. The five-membered rings in molecule **IIa** are almost orthogonal. The dihedral angle between the $C^8C^9C^{10}C^6$ and $C^1C^2C^4C^5$ planes is 92.5 (1)°. This arrangement is stabilized by a weak intramolecular hydrogen bond formed between the other hydrogen atom of the amino group and O^2 in the keto group. The N^1–$H^{1'}\cdots O^2$ distance is 2.54(2) Å, and the angle $N^1H^{1'}O^2$ is 126(2)°. It should be noted that analogous but much stronger hydrogen bond was found in molecule **IIc**, where the distance between the amino hydrogen atom (H^1) and ketone carbonyl oxygen atom (O^1) is equal to 2.23(2) Å. Presumably, the reason is the higher conformational mobility of the open chain in **IIc**, as compared to cyclic bond sequence in **IIa**. The X-ray diffraction data for compounds **IIa** and **IIc** are consistent with the ^{1}H NMR spectra which display separate signals from each hydrogen atom of the amino group.

The reactions of acrolein with tetracyanoethyl derivatives of cyclododecanone and dihydroepiandrosterone (compounds **III** and **V**) did not stop at the stage of formation of the corresponding 3-amino-4-formyl-3-cyclopentene-1,1,2-tricarbonitriles **C** and **D**, respectively, but intramolecular cyclization of the latter afforded 1-azapentalenes **IV** and **VI** (Scheme 2).

Computer simulation (CS Chemo 3D Pro) showed that the distances between the amino and oxo groups in

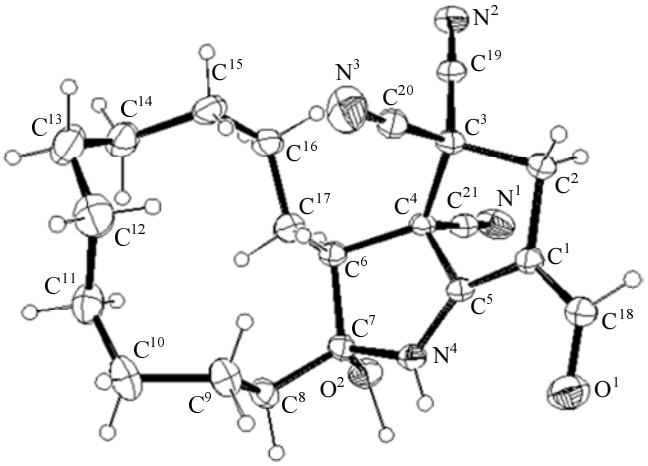


Fig. 3. Structure of the molecule of 3-formyl-4a-hydroxy-1,2,4,4a,5,6,7,8,9,10,11,12,13,14,14a,14b-hexadecahydrocyclododeca[*b*]cyclopenta[*d*]pyrrole-1,1,14b-tricarbonitrile (**IV**) according to the X-ray diffraction data.

intermediates **C** and **D** are equal to 1.88 and 1.94 Å, respectively. These distances are even shorter than the corresponding experimental distances in molecules **IIa** and **IIc** in crystal (see above). We believe that spatial proximity of the amino and oxo groups to each other in intermediates **C** and **D** favors closure of pyrrolidine ring to give compounds **IV** and **VI**. Figure 3 shows the structure of molecule **IV** with atom numbering. As in molecules **IIa** and **IIc**, the five-membered rings in **IV** adopt C^3- and C^6-*envelope* conformations. Due to the presence of a nitrogen atom in the five-membered ring, the bond angle C^1C^5N in **IV** increases to 137.5(1)°; for comparison, the corresponding bond angle in molecule **IIa** ($C^9C^{10}N^1$) is 127.9(1)°. Therefore, the intramolecular hydrogen bond $N–H\cdots O^1$ in structure **IV** is much weaker than in **IIa** and **IIc**. The $HN\cdots O^1$ distance is 2.56(2) Å. Nevertheless, conjugation in the $N–C^5–C^1–C^{10}–O^1$ bond sequence [$N–C^5$ 1.333(2), $C^5–C^1$ 1.351(2), $C^1–C^{10}$ 1.414(2), $C^{10}–O^1$ 1.234(2) Å] is comparable with that in the corresponding fragment of molecule **IIa** or **IIc**. These findings may be rationalized on the basis of analysis of intermolecular hydrogen bonding. The aldehyde carbonyl oxygen atom (O^1) in molecule **IV** is involved in strong intermolecular hydrogen bond with the hydroxy group [$HO^2\cdots O^{1'}$ 1.75(2) Å (–*x*, –*y* + 1, *z*), $\angle O^2HO^{1'}$ 154(2)°], leading to stronger electron density transfer from the nitrogen atom to O^1 through the conjugated bond system.

The reactions of acrolein with tetracyanoethyl-substituted ketones **III** and **V** were carried out under the conditions similar to those in the synthesis of compounds **IIa**–**IIh**. Mixing of compounds **III** and **V** with acrolein in 2-propanol gave 1-azapentalenes **IV** and **VI** in 5–10 min; after 24 h, the product crystallized from the reaction mixture.

β,β,γ,γ-Tetracyanoalkanones are highly reactive compounds. We previously reported on the synthesis of various heterocycles [15–20], mainly pyridine derivatives, on the basis of β,β,γ,γ-tetracyanoalkanones. However, these reactions were performed under relatively severe conditions, in concentrated mineral acids or in the presence of strong bases. In some cases, strong oxidants and reducing agents were used [4]. Ketones of the general formula $R^1C(O)R^2$, where R^1 and R^2 contained in total no more than 5 carbon atoms, were involved in the tetracyanoethylation and heterocyclization processes. It was impossible to obtain cyano-substituted alicyclic and heterocyclic compounds from analogous ketones with bulkier R^1 and R^2 substituents and containing double C=C bonds. The procedure proposed in the present work for the transformation of ketones $R^1C(O)R^2$ into cyclopentene derivatives is free from the above limitation.

EXPERIMENTAL

The IR spectra were recorded on a UR-20 spectrometer from samples dispersed in mineral oil. The ^{1}H NMR spectra were measured from solutions in DMSO-d_6 on a Bruker AM-300 spectrometer operating at 300 MHz. The molecular weights were determined from the mass spectra which were run on a Finnigan MAT Incos 50 instrument (electron impact, 70 eV). The progress of reactions and the purity of products were monitored by TLC on Silufol UV-254 plates.

Selected single crystals of compounds **IIa**, **IIc**, and **IV** were analyzed on an Enraf–Nonius CAD-4 four-circle diffractometer (MoK_α irradiation, graphite monochromator, ω-scanning). The unit cell parameters were determined and refined from 25 reflections in the Θ range from 11 to 20°. All these compounds crystallized in the monoclinic crystal system; space group $P2_1/n$ (**IIa**, **IV**) and $P2_1/c$ (**IIc**). Unit cell parameters: **IIa**: a = 8.404(1), b = 14.067(2), c = 11.448(2) Å; β = 101.41(2)°; V = 1328.3(3) Å^3; Z = 4; **IV**: a = 12.586(2), b = 11.522(1), c = 14.062(2) Å; β = 109.62(2)°; V = 1921.7(3) Å^3; Z = 4; **IIc**: a = 9.144(2), b = 19.216(4), c = 8.365(2) Å; β = 93.43(2)°; V = 1467.2(3) Å^3, Z = 4. The structures were solved, and their positional and thermal parameters were refined, in full-matrix approximation, using SHELX software package [22]. The positions of hydrogen atoms were determined by the Fourier difference syntheses and were refined in isotropic approximation. The positions and thermal oscillation tensors of non-hydrogen atoms were refined in full-matrix anisotropic approximation. All non-zero reflections were used in the refinement (2605, 2875, and 3013 reflections for compounds **IIa**, **IIc**, and **IV**, respectively). The divergence factors were calculated from 1971 (**IIa**), 2092 (**IIc**), or 1838 reflections (**IV**) with $I > 2\sigma(I)$ and were 0.042, 0.47, and 0.052, respectively. No correction for absorption was introduced, taking into account the low linear absorption coefficient.

β,β,γ,γ-Tetracyanoalkanones Ia–Ih, III, and V (*general procedure*). Appropriate ketone, 0.005 mol, was added to 0.005 mol of tetracyanoethylene in 10 ml of dioxane. When the blue color (due to tetracyanoethylene–hydroquinone complex) disappeared, the mixture was diluted with water, and an oily material separated and gradually crystallized. The crystalline

product was filtered off and washed with water and cold 2-propanol.

1-(2-Oxocyclopentyl)-1,1,2,2-ethanetetracarbonitrile (Ia). Yield 93%, mp 105–106°C (from 2-propanol). ^{1}H NMR spectrum, δ, ppm: 1.86 m (2H, CH_2), 2.13 m (2H, CH_2), 2.5 m (2H, CH_2), 3.54 t (1H, CHCO, J = 7.8 Hz), 5.68 s [1H, $CH(CN)_2$]. Found, %: C 62.37; H 3.66; N 26.33. $C_{11}H_8N_4O$. Calculated, %: C 62.26; H 3.80; N 26.40.

5,5-Dimethyl-4-oxo-1,1,2,2-hexanetetracarbonitrile (Ib). Yield 74%, mp 123–124°C (from 2-propanol). ^{1}H NMR spectrum, δ, ppm: 0.97 s [9H, $(CH_3)_3$], 3.43 s (2H, CH_2CO), 6.56 s [1H, $CH(CN)_2$]. Found, %: C 63.31; H 5.24; N 24.67. $C_{12}H_{12}N_4O$. Calculated, %: C 63.15; H 5.30; N 24.55.

6-Methyl-4-oxo-5-heptene-1,1,2,2-tetracarbonitrile (Ic). Yield 88%, mp 111–112°C (from 2-propanol). ^{1}H NMR spectrum, δ, ppm: 1.76 s [6H, $(CH_3)_2$], 3.54 s (2H, CH_2CO), 6.54 s [1H, $CH(CN)_2$]. Found, %: C 63.89; H 4.44; N 24.62. $C_{12}H_{10}N_4O$. Calculated, %: C 63.71; H 4.46; N 24.76.

4-(4-Chlorophenyl)-4-oxo-1,1,2,2-butanetetracarbonitrile (Id). Yield 95%, mp 135–136°C (from 2-propanol). ^{1}H NMR spectrum, δ, ppm: 3.96 s (2H, CH_2CO), 5.98 s [1H, $CH(CN)_2$], 7.11 d (2H, *o*-H, J = 8.2 Hz), 7.41 d (2H, *m*-H, J = 8.2 Hz). Found, %: C 59.63; H 2.41; N 19.81. $C_{14}H_7ClN_4O$. Calculated, %: C 59.48; H 2.50; N 19.82.

4-(1-Adamantyl)-4-oxo-1,1,2,2-butanetetracarbonitrile (Ie). Yield 84%, mp 145–146°C. ^{1}H NMR spectrum, δ, ppm: 1.64 m and 1.88 m (6H each, CH_2), 2.08 m (3H, CH), 3.58 s (2H, CH_2CO), 7.03 s [1H, $CH(CN)_2$]. Found, %: C 70.49; H 5.99; N 18.21. $C_{18}H_{18}N_4O$. Calculated, %: C 70.57; H 5.92; N 18.29.

1-(3-Isopropyl-6-methyl-2-oxocyclohexyl)-1,1,-2,2-ethanetetracarbonitrile (If). Yield 81%, mp 127–128°C. ^{1}H NMR spectrum, δ, ppm: 0.85 d (3H, CH_3, J = 6.0 Hz), 0.93 d (3H, CH_3, J = 6.0 Hz), 1.44 d (3H, CH_3, J = 6.4 Hz), 1.58–2.27 m [6H, CH_2CH_2, C**H**$(CH_3)_2$, C**H**CH_3], 2.52 m (1H, CH_2C**H**CO), 3.81 d (1H, CHCO, J = 7.9 Hz), 7.01 s [1H, $CH(CN)_2$]. Found, %: C 68.09; H 6.44; N 19.81. $C_{16}H_{18}N_4O$. Calculated, %: C 68.06; H 6.43; N 19.84.

(*E*)-4-Oxo-6-(2,6,6-trimethyl-1-cyclohexenyl)-5-hexene-1,1,2,2-tetracarbonitrile (Ig). Yield 62%, mp 182–183°C. ^{1}H NMR spectrum, δ, ppm: 1.1 s [6H, $C(CH_3)_2$], 1.48 m [2H, C**H**$_2$C$(CH_3)_2$], 1.63 m [2H, C**H**$_2$CH_2C(CH_3)=C], 1.82 s (3H, CH_3C=C), 2.13 m [2H, C**H**$_2$C(CH_3)=C], 3.66 s (2H, CH_2CO), 6.24 d (1H, CH=C**H**CO, J = 16.3 Hz), 7.47 d (1H, C**H**=CHCO, J = 16.3 Hz), 6.52 s [1H, $CH(CN)_2$]. Found, %: C 71.34; H 6.40; N 17.55. $C_{19}H_{20}N_4O$. Calculated, %: C 71.23; H 6.29; N 17.49.

(*E*)-4-Oxo-6-(2,6,6-trimethyl-2-cyclohexenyl)-5-hexene-1,1,2,2-tetracarbonitrile (Ih). Yield 56%, mp 175–176°C. ^{1}H NMR spectrum, δ, ppm: 1.04 s [6H, $C(CH_3)_2$], 1.35 m [2H, C**H**$_2$C$(CH_3)_2$], 1.75 s (3H, CH_3C=C), 2.18 m [2H, C**H**$_2$CH=C(CH_3)], 3.47 d (1H, C**H**CH=CH, J = 9.6 Hz), 3.65 s (2H, CH_2CO), 5.17 t [1H, C**H**=C(CH_3), J = 8.2 Hz], 6.08 d (1H, CH=C**H**CO, J = 16.1 Hz), 7.32 d.d (1H, C**H**=CHCO, J = 16.1, 9.6 Hz), 6.66 s [1H, $CH(CN)_2$]. Found, %: C 71.24; H 6.21; N 17.42. $C_{19}H_{20}N_4O$. Calculated, %: C 71.23; H 6.29; N 17.49.

1-(2-Oxocyclododecyl)-1,1,2,2-ethanetetracarbonitrile (III). Yield 86%, mp 156–157°C. ^{1}H NMR spectrum, δ, ppm: 1.1–1.9 m [20H, $(CH_2)_{10}$], 2.88 t (1H, CHCO, J = 7.9 Hz), 6.56 s [1H, $CH(CN)_2$]. Found, %: C 69.82; H 7.18; N 18.01. $C_{28}H_{22}N_4O$. Calculated, %: C 69.65; H 7.14; N 18.05.

16-(1,1,2,2-Tetracyanoethyl)dihydroepiandrosterone (V). Yield 72%, mp 156–157°C. ^{1}H NMR spectrum, δ, ppm: 6.18 s (1H, COH), 5.63 s [1H, $CH(CN)_2$], 5.26 t (1H, CH=C, J = 6.9 Hz), 4.57 s (1H, CHO**H**), 3.24 m (1H, C**H**OH), 2.56 t (1H, CHCO, J = 7.1 Hz), 2.2–1.05 m (17H), 0.98 s (3H, CH_3), 0.89 s (3H, CH_3). Found, %: C 71.94; H 6.84; N 13.42. $C_{25}H_{28}N_4O_2$. Calculated, %: C 72.09; H 6.78; N 13.45.

2-Substituted 3-amino-4-formyl-3-cyclopentene-1,1,2-tricarbonitriles IIa–IIh and 1-azapentalenes IV and VI (*general procedure*). Acrolein, 0.015 mol, was added dropwise to 0.01 mol of β,β,γ,γ-tetracyanoalkanone **Ia**–**Ih**, **III**, or **V** in 20 ml of isopropyl alcohol. The mixture was stirred until it became homogeneous. Usually, crystalline product separated in 1–2 days. The precipitate was filtered off and washed with 2-propanol. An additional amount of the product was isolated by diluting the filtrate with 40 ml of water. If necessary, the product was recrystallized from 2-propanol.

3-Amino-4-formyl-2-(2-oxopentyl)-3-cyclopentene-1,1,2-tricarbonitrile (IIa). Yield 91%, mp 155–156°C. ^{1}H NMR spectrum, δ, ppm: 1.84 m (2H, CH_2), 2.1 m (2H, CH_2), 2.47 m (2H, CH_2), 3.41 d [1H, $CH_2C(CN)_2$, J = 15.0 Hz], 3.48 d [1H, $CH_2C(CN)_2$, J = 15.0 Hz], 3.51 d.d (1H, CHCO, J = 8.3, 7.6 Hz), 7.77 s (2H, NH_2), 9.69 s (1H, COH). Found, %: C 62.73; H 4.62; N 20.89. $C_{14}H_{12}N_4O_2$. Calculated, %: C 62.68; H 4.51; N 20.88.

3-Amino-4-formyl-2-(3,3-dimethyl-2-oxobutyl)-3-cyclopentene-1,1,2-tricarbonitrile (IIb). Yield 83%, mp 139–140°C. ^{1}H NMR spectrum, δ, ppm: 0.98 s (9H, CH_3), 3.44 d [1H, $CH_2C(CN)_2$, J = 14.9 Hz], 3.49 d (1H, CH_2CO, J = 18.8 Hz), 3.55 d [1H, $CH_2C(CN)_2$, J = 14.9 Hz], 4.14 d (1H, CH_2CO, J = 18.8 Hz), 7.86 s (2H, NH_2), 9.62 s (1H, COH). Found, %: C 63.44; H 5.54; N 19.82. $C_{15}H_{16}N_4O_2$. Calculated, %: C 63.37; H 5.67; N 19.71.

3-Amino-4-formyl-2-(4-methyl-2-oxo-3-pentenyl)-3-cyclopentene-1,1,2-tricarbonitrile (IIc). Yield 67%, mp 151–152°C. ^{1}H NMR spectrum, δ, ppm: 1.8 s [6H, $(CH_3)_2$], 3.51 d [1H, $CH_2C(CN)_2$, J = 14.9 Hz], 3.65 d [1H, $CH_2C(CN)_2$, J = 14.9 Hz], 3.68 d (1H, CH_2CO, J = 18.8 Hz), 4.13 d (1H, CH_2CO, J = 18.8 Hz), 7.16 s (1H, C=CHCO), 7.94 s (2H, NH_2), 9.56 s (1H, COH). Found, %: C 63.80; H 4.94; N 19.91. $C_{15}H_{14}N_4O_2$. Calculated, %: C 63.82; H 5.00; N 19.85.

3-Amino-2-[2-(4-chlorophenyl)-2-oxoethyl]-4-formyl-3-cyclopentene-1,1,2-tricarbonitrile (IId). Yield 89%, mp 162–163°C. ^{1}H NMR spectrum, δ, ppm: 3.46 d [1H, $CH_2C(CN)_2$, J = 14.8 Hz], 3.49 d (1H, CH_2CO, J = 18.8 Hz), 3.58 d [1H, $CH_2C(CN)_2$, J = 14.8 Hz], 4.23 d (1H, CH_2CO, J = 19.1 Hz), 3.51 d (1H, CHCO, J = 18.8 Hz), 7.1 d (2H, *o*-H, J = 8.2 Hz), 7.43 d (2H, *m*-H, J = 8.2 Hz), 7.74 s (2H, NH_2), 9.72 s (1H, COH). Found, %: C 60.33; H 3.33; N 16.48. $C_{17}H_{11}ClN_4O_2$. Calculated, %: C 60.28; H 3.27; N 16.54.

2-[2-(1-Adamantyl)-2-oxoethyl]-3-amino-4-formyl-3-cyclopentene-1,1,2-tricarbonitrile (IIe). Yield 92%, mp 152–153°C. ^{1}H NMR spectrum, δ, ppm: 1.64 m and 1.88 m (6H each, CH_2), 2.08 m (3H, CH), 3.38 d [1H, $CH_2C(CN)_2$, J = 14.7 Hz], 3.53 d (1H, CH_2CO, J = 19.2 Hz), 3.61 d [1H, $CH_2C(CN)_2$, J = 14.7 Hz], 4.14 d (1H, CH_2CO, J = 19.2 Hz), 7.99 s (2H, NH_2), 9.58 s (1H, COH). Found, %: C 69.54; H 6.01; N 15.41. $C_{21}H_{22}N_4O_2$. Calculated, %: C 69.59; H 6.12; N 15.46.

3-Amino-4-formyl-2-(3-isopropyl-6-methyl-2-oxocyclohexyl)-3-cyclopentene-1,1,2-tricarbonitrile (IIf). Yield 84%, mp 171–172°C. ^{1}H NMR spectrum, δ, ppm: 0.84 d (3H, CH_3, J = 6.0 Hz), 0.93 d (3H, CH_3, J = 6.0 Hz), 1.42 d (3H, CH_3, J = 6.5 Hz), 1.57–2.28 m [6H, CH_2CH_2, C**H**$(CH_3)_2$, C**H**CH_3], 2.5 m (1H, CH_2C**H**CO), 3.53 d [1H, $CH_2C(CN)_2$, J = 14.5 Hz], 3.71 d [1H, $CH_2C(CN)_2$, J = 15.0 Hz], 3.81 d (1H, CHCO, J = 8.7 Hz), 7.98 s (2H, NH_2), 9.49 s (1H, COH). Found, %: C 67.51; H 6.46; N 16.47. $C_{19}H_{22}N_4O_2$. Calculated, %: C 67.44; H 6.55; N 16.56.

3-Amino-4-formyl-2-[(*E*)-2-oxo-4-(2,6,6-trimethyl-1-cyclohexenyl)-3-butenyl]-3-cyclopentene-1,1,2-tricarbonitrile (IIg). Yield 65%, mp 188–189°C. ^{1}H NMR spectrum, δ, ppm: 1.1 s [6H, $C(CH_3)_2$], 1.48 m [2H, C**H**$_2C(CH_3)_2$], 1.63 m [2H, C**H**$_2CH_2$-$C(CH_3)$=C], 1.82 s (3H, CH_3C=C), 2.13 m [2H, C**H**$_2C(CH_3)$=C], 3.44 d [1H, $CH_2C(CN)_2$, J = 14.9 Hz], 3.61 d [1H, $CH_2C(CN)_2$, J = 14.9 Hz], 3.65 d (1H, CH_2CO, J = 18.5 Hz), 4.18 d (1H, CH_2CO, J = 18.5 Hz), 6.24 d (1H, CH=C**H**CO, J = 16.3 Hz), 7.47 d (1H, C**H**=CHCO, J = 16.3 Hz), 7.99 s (2H, NH_2), 9.58 s (1H, CHO). Found, %: C 70.25; H 6.37; N 14.79. $C_{22}H_{24}N_4O_2$. Calculated, %: C 70.20; H 6.43; N 14.88.

3-Amino-4-formyl-2-[(*E*)-2-oxo-4-(2,6,6-trimethyl-2-cyclohexenyl)-3-butenyl]-3-cyclopentene-1,1,2-tricarbonitrile (IIh). Yield 69%, mp 192–193°C. ^{1}H NMR spectrum, δ, ppm: 1.04 s [6H, $C(CH_3)_2$], 1.35 m [2H, C**H**$_2C(CH_3)_2$], 1.75 s (3H, CH_3C=C), 2.18 m [2H, C**H**$_2$CH=$C(CH_3)$], 3.43 d [1H, $CH_2C(CN)_2$, J = 14.9 Hz], 3.47 d (1H, C**H**CH=CH, J = 9.6 Hz), 3.6 d [1H, $CH_2C(CN)_2$, J = 14.9 Hz], 3.65 d (1H, CH_2CO, J = 18.4 Hz), 4.12 d (1H, CH_2CO, J = 18.4 Hz), 5.17 t [1H, C**H**=$C(CH_3)$, J = 8.2 Hz], 6.08 d (1H, CH=C**H**CO, J = 16.1 Hz), 7.32 d.d (1H, C**H**=CHCO, J = 16.1, 9.6 Hz), 7.92 s (2H, NH_2), 9.61 s (1H, CHO). Found, %: C 70.18; H 6.48; N 14.87. $C_{22}H_{24}N_4O_2$. Calculated, %: C 70.20; H 6.43; N 14.88.

3-Formyl-4a-hydroxy-1,2,4,4a,5,6,7,8,9,10,11,12,-13,14,14a,14b-hexadecahydrocyclododeca[*b*]cyclopenta[*d*]pyrrole-1,1,14b-tricarbonitrile (IV). Yield 78%, mp 192–193°C. ^{1}H NMR spectrum, δ, ppm: 1.1–1.9 m [20H, $(CH_2)_{10}$], 2.68 d (1H, C**H**COH, J = 8.4 Hz), 3.44 d [1H, $CH_2C(CN)_2$, J = 15.0 Hz], 3.83 d [1H, $CH_2C(CN)_2$, J = 15.0 Hz], 6.36 s (1H, OH), 9.53 s (1H, CHO), 9.94 s (1H, NH). Found, %: C 68.75; H 7.19; N 15.28. $C_{21}H_{26}N_4O_2$. Calculated, %: C 68.83; H 7.15; N 15.29.

8-Formyl-2,6b-dihydroxy-4a,6a-dimethyl-2,3,4,-4a,4b,5,6,6a,6b,7,9,10,10a,10b,11,11a,11b,12-octadecahydro-1*H*-cyclopenta[*b*]naphtho[2',1':4,5]-indeno[2,1-*e*]pyrrole-10,10,10a-tricarbonitrile (VI). Yield 63%, mp 171–172°C. ^{1}H NMR spectrum, δ, ppm: 9.68 s (1H, CHO), 9.67 s (1H, NH), 6.36 s (1H, COH), 5.27 t (1H, CH=C, J = 6.9 Hz), 4.57 s (1H, CHO**H**), 3.24 m (1H, C**H**OH), 3.14 d [1H, $CH_2C(CN)_2$, J = 14.6 Hz], 2.98 d [1H, $CH_2C(CN)_2$, J = 14.6 Hz], 2.94 t [1H, C**H**C(OH)NH, J = 7.7 Hz], 2.2–1.05 m (17H), 0.98 s (3H, CH_3), 0.89 s (3H, CH_3). ^{13}C NMR spectrum (125.7 MHz), δ_C, ppm: 199.39, 165.04, 141.36, 119.67, 114.39, 112.72, 112.21, 97.74, 69.86, 50.32, 49.12, 48.10, 45.38, 42.07, 39.81, 39.64, 39.48,

39.31, 39.14, 38.98, 38.83, 36.77, 36.00, 31.63, 31.30, 30.92, 30.88, 30.80, 25.34, 19.84, 18.97, 14.23. Found, %: C 71.16; H 6.82; N 11.86. $C_{28}H_{35}N_4O_3$. Calculated, %: C 71.18; H 6.79; N 11.84.

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