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Synthesis of 2-(1,5,9-Triazabicyclo[7.3.1]tridec-10-en-5-yl)-4-methylthiobutanoic Acid Derivatives

V. P. Krivonogov, G. A. Sivkova, E. A. Belaya, N. V. Greben'kova, G. G. Kozlova, I. B. Abdrakhmanov, L. V. Spirikhin, and R. T. Mannapova

Institute of Organic Chemistry, Ufa Research Center, Russian Academy of Sciences, pr. Oktyabrya 71, Ufa, 450054 Bashkortostan, Russia

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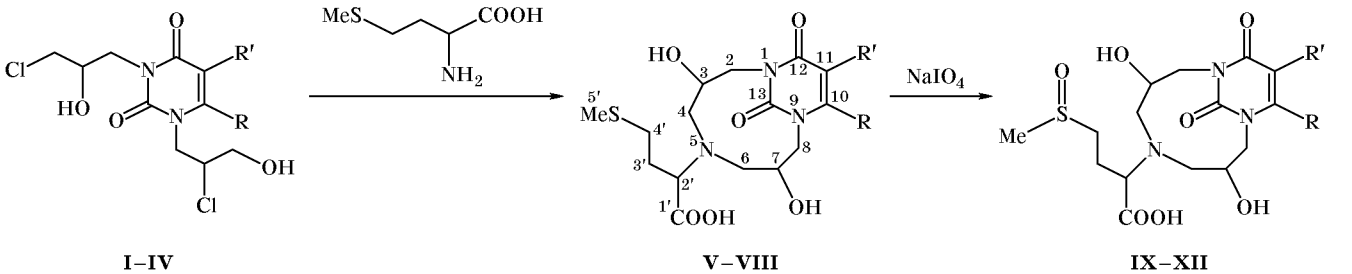
Abstract—Reactions of 1,3-bis(3-chloro-2-hydroxypropyl)uracil, 1,3-bis(3-chloro-2-hydroxypropyl)-6-methyluracil, 1,3-bis(3-chloro-2-hydroxypropyl)-5-hydroxy-6-methyluracil, and 1,3-bis(3-chloro-2-hydroxypropyl)-5-fluorouracil with 2-amino-4-methylthiobutanoic acid (methionine) were studied for the first time.

L-Methionine (2-amino-4-methylthiobutanoic acid) $CH_3S(CH_2)_2CH(NH_2)COOH$ is an essential amino acid which is contained in proteins. *S*-Adenosylmethionine is a donor of methyl groups in mammalians and humans (e.g., in the biosynthesis of choline and adrenalin). Methionine is used as a forage additive and as a medicine. Methylated methionine (*S*-methylmethionine sulfonium chloride) is a vitamin-like substance.

We previously synthesized a large number of pyrimidine derivatives exhibiting immunotropic, antiphlogistic, antiradical, and membrane-stabilizing activity [1–5]. With the goal of searching for new pharmacologically active compounds, as well as new extragents and complexing agents, we have developed a scheme of synthesis of 10-alkyl-2-(3,7-dihydroxy-12,13-dioxo-1,5,9-triazabicyclo[7.3.1]tridec-10-en-5-yl)-4-methylthiobutanoic acids starting from methionine and 1,3-bis(3-chloro-2-hydroxypropyl)uracil, 1,3-bis(3-chloro-2-hydroxypropyl)-6-methyluracil, 1,3-bis(3-chloro-2-hydroxypropyl)-5-hydroxy-6-methyluracil, and 1,3-bis(3-chloro-2-hydroxypropyl)-5-fluorouracil in methanol in the presence of potassium carbonate. The products were oxidized to the corresponding sulfoxides with sodium periodate in aqueous alcohol (Scheme 1). The structure of the synthesized compounds was proved by the IR and ^1H and ^{13}C NMR spectra and elemental analyses.

The IR spectra of the products contained absorption bands in the region 1620–1720 cm^{-1}, which are typical of the uracil fragment (ν C=O, ν=NC=O). Absorption bands in the region 1060–1240 cm^{-1} are characteristic of compounds having a tertiary nitrogen atom (–N=); bands at 3300–3500 cm^{-1} arise from stretching vibrations of the hydroxy groups. Compounds **III**, **VII**, **XI** show in the IR spectra a band at 3400 cm^{-1} belonging to the hydroxy group on C^{11}, which is involved in hydrogen bond. Absorption bands at 960–1030 cm^{-1} (rocking vibrations), 1288–1320 cm^{-1} (δ_s, symmetric bending vibrations), and 1415–1430 cm^{-1} (δ_{as}, asymmetric vibrations) are typical of the $RSCH_3$ fragment. A band at 2468 cm^{-1}

Scheme 1.



I–IV **V–VIII** **IX–XII**

I, **V**, **IX**, R = R′ = H; **II**, **VI**, **X**, R = Me, R′ = H; **III**, **VII**, **XI**, R = Me, R′ = OH; **IV**, **VIII**, **XII**, R = H, R′ = F.

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corresponds to stretching vibrations of amino acid salt. The C–S bond gives rise to absorption in the region 640–690 cm^{-1}, and the S=O group in compounds **IX**–**XII** is responsible for absorption bands in the region 1040–1080 cm^{-1}.

In the ^{13}C NMR spectra of all the products, carbon signals of the uracil fragment appear at their usual positions, δ_C, ppm: 164 (C^{12}), 155 (C^{13}), 148 (C^{10}). The signal from the methylene carbon atom ($C^{4'}$) adjacent to the S=O group in compounds **IX**–**XII** is displaced downfield by 20 ppm (δ_C 49.7 ppm) relative to the corresponding signal of the methylthio derivatives (δ_C 20.6 ppm). The signal from the methyl group in the sulfoxides is located at δ_C 39 ppm (against δ_C 15.3 ppm in the sulfides), and the carboxy group ($C^{1'}$) gives a signal at δ_C 170–177 ppm.

In the ^1H NMR spectra of **I**, **V**, and **IX**, signals from protons on C^{10} and C^{11} (uracil fragment) appear as doublets with a coupling constant *J* of 6.5–7.3 Hz. We observed no formation of diastereoisomers differing by configuration of the C^3 and C^7 centers. Both sulfides **V**–**VIII** and sulfoxides **IX**–**XII** showed no doubling of signals in the ^{13}C NMR spectra, though some broadening of the C^3 and C^7 signals was observed. Presumably, this is the result of dynamic hydrogen bonding between the hydroxy groups on C^3 and C^7 and carbonyl oxygen atoms at C^{13} and C^{12}. The formation of hydrogen bond between the hydroxy group on C^3 and the C^{12}=O group in compound **V** is confirmed by displacement of the C^{11} signal from δ_C 126.42 to 103.26 ppm; the signal from C^{11} in the spectrum of **VII** shifts due to formation of a strong hydrogen bond between C^{11}–OH and C^{12}=O.

EXPERIMENTAL

The ^1H and ^{13}C NMR spectra were recorded on a Bruker AM spectrometer (300 MHz for ^1H and 75.7 MHz for ^{13}C) from 10% and 10–20% solutions, respectively, in $CDCl_3$. The chemical shifts are given relative to tetramethylsilane. The IR spectra were obtained on a UR-20 spectrophotometer (Carl Zeiss Jena) with NaCl and LiF prisms; samples were prepared as films (liquids) or suspensions in mineral oil. The melting points were determined on a Boetius device. Elemental analysis was performed using an M-185B CHN-Analyzer. The progress of reactions was monitored, and the purity of the products was checked, by TLC on Silufol UV-254 plates using ethanol–aqueous ammonia (4:1) as eluent; spots were detected under UV light (λ 254 nm) or by treatment with iodine vapor.

2-(3,7-Dihydroxy-12,13-dioxo-1,5,9-triazabicyclo[7.3.1]tridec-10-en-5-yl)-4-methylthiobutanoic acid (V). Potassium carbonate, 23.4 g (0.17 mol), tetrabutylammonium bromide, 3 g, and optically inactive methionine, 12.8 g (0.082 mol), were added to a solution of 22.4 g (0.082 mol) of 1,3-bis(3-chloro-2-hydroxypropyl)uracil in 150 ml of methanol. The mixture was heated to the boiling point, stirred for 4 h at that temperature, and left overnight. The crystals were filtered off, the filtrate was acidified with concentrated hydrochloric acid (10 ml), the precipitate was filtered off, and the filtrate was evaporated under reduced pressure. The residue was a thick liquid, 36 g. Found, %: C 39.80; H 6.40; Cl 2.10; K 9.30; N 9.40; S 7.16. $C_{15}H_{22}KN_3O_6S \cdot 2H_2O$. Calculated, %: C 40.26; H 5.86; K 8.74; N 9.39; S 7.16.

To the resulting potassium 2-(3,7-dihydroxy-12,13-dioxo-1,5,9-triazabicyclo[7.3.1]tridec-10-en-5-yl)-4-methylthiobutanoate we added 50 ml of methanol, 50 ml of DMF, and 40 ml of hexane. The solution was neutralized with concentrated hydrochloric acid, the precipitate was filtered off, and the solvent was distilled off from the filtrate to obtain 23 g (70%) of compound **V**. The product is readily soluble in alcohol, acetone, chloroform, DMF, and water and insoluble in hexane. The product was dissolved in methanol, and the solution was passed through a column charged with silica gel (with subsequent elution with methanol). Evaporation of the eluate gave 15 g (42%) of compound **V** as a yellow powder. mp 158–160°C, R_f 0.64 (alcohol–aqueous ammonia, 4:1). IR spectrum, ν, cm^{-1}: 632, 690 (C–S); 1040–1280 (=N–); 1324, 1400 ($RSCH_3^+$); 1652, 1720 (C=C), C=O, =N–C=O); 2468 (NH); 1130, 1200, 3286, 3600 (OH). ^1H NMR spectrum (D_2O), δ, ppm: 1.2–1.40 m (2H, 3′-H_2); 2.11 s (3H, CH_3S); 2.50–2.60 m (4H, 4-H_2, 4′-H_2); 2.80 d (2H, 6-H_2, *J* = 6 Hz); 3.0 d (2H, 2-H_2, *J* = 6 Hz); 3.35 t (1H, 2′-H, *J* = 6 Hz); 3.50–3.70 m (2H, 3-H, 7-H); 3.8 d (2H, 8-H_2, *J* = 6 Hz); 5.80 d (1H, 11-H, *J* = 7.3 Hz); 7.15 s (3H, OH); 7.93 d (1H, 10-H, *J* = 6.0 Hz). ^{13}C NMR spectrum (D_2O), δ_C, ppm: 177.8 ($C^{1'}$); 167.49 (C^{12}); 155.19 (C^{13}); 138.64 (C^{10}); 102.3 (C^{11}); 69.18 ($C^{2'}$); 66.09 (C^3); 65.52 (C^7); 56.98 (C^4); 56.67 (C^6); 47.27 (C^8); 46.11 (C^2); 32.7 ($C^{3'}$); 25.75 ($C^{4'}$); 17.50 ($C^{5'}$). Found, %: C 45.64; H 6.00; N 10.30; S 7.79. $C_{15}H_{23}N_3O_6S \cdot H2O$. Calculated, %: C 46.03; H 6.44; N 10.74; S 8.19.

2-(3,7-Dihydroxy-10-methyl-12,13-dioxo-1,5,9-triazabicyclo[7.3.1]tridec-10-en-5-yl)-4-methylthiobutanoic acid (VI) was synthesized as described above for compound **V** from 22 g (0.07 mol) of compound **II** in 150 ml of methanol, 20 g (0.145 mol)

of K_2CO_3, 2 g (0.006 mol) of tetrabutylammonium bromide, and 11.2 g (0.07 mol) of methionine. The corresponding potassium salt, 25.4 g, was isolated as a thick liquid readily soluble in alcohol, acetone, and water and insoluble in hexane. Found, %: C 39.45; H 7.30; K 15.84; N 8.35; S 6.18. $C_{16}H_{23}K_2N_3O_6S \cdot H_2O$. Calculated, %: C 39.90; H 5.23; K 16.24; N 8.72; S 6.66. The salt was dissolved in 50 ml of methanol, 50 ml of hexane was added, and the mixture was acidified with concentrated hydrochloric acid to pH 6.0. The precipitate was filtered off, and the filtrate was evaporated to obtain 19 g (67%) of 2-(3,7-dihydroxy-10-methyl-12,13-dioxo-1,5,9-triazabicyclo-[7.3.1]tridec-10-en-5-yl)-4-methylthiobutanoic acid (**VI**). The product was additionally purified by column chromatography on silica gel using acetone–methanol (1:1) as eluent. Yield 50%. R_f 0.52 (alcohol–aqueous ammonia, 4:1). IR spectrum, ν, cm^{-1}: 632, 690 (C–S); 1040–1280 (=N–); 1324, 1400 (RSCH$_3$); 1652, 1720 (C=O, =N–C=O); 2468 ($\overset{+}{N}$H); 3286, 3600 (OH). ^{1}H NMR spectrum (D_2O), δ, ppm: 1.3–1.45 m (2H, 3′-H_2); 2.04 s (3H, 10-CH_3); 2.11 s (3H, CH_3S); 2.45–2.65 m (6H, 4′-H_2, 4-H_2, 6-H_2); 2.88 d (4H, 2-H_2, 8-H_2, J = 7 Hz); 3.35 t (1H, 1′-H, J = 6.5 Hz); 3.50–3.70 m (2H, 3-H, 7-H); 5.68 s (1H, 11-H); 7.14 s (3H, OH). ^{13}C NMR spectrum (D_2O), δ_C, ppm: 170.8 ($C^{1'}$); 164.00 (C^{12}); 155.19 (C^{13}); 148 (C^{10}); 103.26 (C^{11}); 69.18 ($C^{2'}$); 66.09 (C^3); 65.52 (C^7); 56.98 (C^4, C^6); 47.27 (C^2, C^8); 32.87 ($C^{3'}$); 26.00 ($C^{4'}$); 17.64 ($C^{5'}$); 15.50 (10-CH_3). Found, %: C 46.00; H 7.50; N 9.70; S 7.40. $C_{16}H_{25}N_3O_6S \cdot 2H_2O$. Calculated, %: C 46.48; H 7.07; N 10.16; S 7.75.

2-(3,7,11-Trihydroxy-10-methyl-12,13-dioxo-1,5,9-triazabicyclo[7.3.1]tridec-10-en-5-yl)-4-methylthiobutanoic acid (VII) was synthesized as described above for compound **V** from 26.4 g (0.08 mol) of uracil **III** in 100 ml of methanol, 23.4 g (0.17 mol) of K_2CO_3, 3.5 g (0.0098 mol) of tetrabutylammonium bromide, and 12.8 g (0.08 mol) of methionine. The corresponding potassium salt, 45.1 g, was isolated as a thick liquid. Found, %: C 35.60; H 4.30; K 22.37; N 7.40; S 5.58. $C_{16}H_{23}K_3N_3O_7S \cdot H_2O$. Calculated, %: C 35.80; H 4.69; K 21.85; N 7.83; S 5.97. The salt was dissolved in a mixture of 50 ml of acetone and 150 ml of methanol, the solution was acidified with concentrated hydrochloric acid to pH 6, the precipitate was filtered off, and the solvent was distilled off from the filtrate to obtain 35.00 g (81%) of a light yellow liquid readily soluble in alcohol, acetone, water, and DMF and insoluble in hexane. The product was additionally purified by column chromatography on silica gel using acetone–methanol (1:1) as eluent. Yield 50%. R_f 0.44 (alcohol–aqueous ammonia, 4:1). IR spectrum, ν, cm^{-1}: 670, 720 (C–S); 1050–1250 (=N–); 1320, 1370 (δ_s CH_3); 1460, 1590, 1660, 1715 (C=O, =N–C=O); 3360, 3430, 3500 (OH). ^{1}H NMR spectrum (D_2O), δ, ppm: 1.3–1.45 m (2H, 3′-H_2); 2.04 s (3H, 10-CH_3); 2.11 s (3H, CH_3S); 2.45–2.65 m (6H, 4′-H_2, 4-H_2, 6-H_2); 2.88 d (4H, 2-H_2, 8-H_2, J = 7 Hz); 3.35 t (1H, 2′-H, J = 7 Hz); 3.6 m (2H, 3-H, 7-H); 8.0 s (4H, OH). ^{13}C NMR spectrum (D_2O), δ_C, ppm: 177.8 ($C^{1'}$); 163.49 (C^{12}); 150.19 (C^{13}); 123.10 (C^{10}); 129.26 (C^{11}); 69.18 ($C^{2'}$); 66.09 (C^3); 65.52 (C^7); 56.98 (C^4); 56.67 (C^6); 47.27 (C^2, C^8); 32.87 ($C^{3'}$); 25.75 ($C^{4'}$); 17.50 ($C^{5'}$); 15.50 (10-CH_3). Found, %: C 43.30; H 6.60; N 9.97; S 7.08. $C_{16}H_{25}N_3O_7S \cdot 2H_2O$. Calculated, %: C 43.73; H 6.65; N 9.56; S 7.30.

2-(11-Fluoro-3,7-dihydroxy-12,13-dioxo-1,5,9-triazabicyclo[7.3.1]tridec-10-en-5-yl)-4-methylthiobutanoic acid (VIII) was synthesized as described above for compound **V** from 6.1 g (0.0194 mol) of compound **IV** in 50 ml of methanol, 5.52 g (0.04 mol) of K_2CO_3, 1.0 g (0.004 mol) of tetrabutylammonium bromide, and 3.0 g (0.02 mol) of methionine. The corresponding potassium salt, 12.1 g, was isolated as a thick light yellow liquid readily soluble in alcohol, acetone, water, and DMF and insoluble in hexane. Found, %: C 30.87; H 4.40; F 2.85; K 20.50; N 6.88; S 5.20. $C_{15}H_{19}FK_3N_3O_6S \cdot 4H_2O$. Calculated, %: C 31.18; H 4.71; F 3.29; K 20.30; N 7.27; S 5.55. The salt was dissolved in a mixture of 50 ml of acetone and 100 ml of methanol, the solution was acidified with concentrated hydrochloric acid to pH 6, the precipitate was filtered off, and the solvent was distilled off to obtain 6.48 g (75%) of a light yellow liquid, readily soluble in alcohol, acetone, water, and DMF and insoluble in hexane. Compound **VIII** was additionally purified by column chromatography on silica gel using methanol as eluent. Light yellow thick liquid. Yield 45%. R_f 0.71. IR spectrum, ν, cm^{-1}: 660, 720 (C–S); 1050–1250 (=N–); 1320, 1370 (δ_s CH_3); 1460, 1600, 1660, 1715 (C=O, =N–C=O); 3360, 3430, 3500 (OH). ^{1}H NMR spectrum (D_2O), δ, ppm: 1.3–1.45 m (2H, 3′-H_2); 2.11 s (3H, CH_3S); 2.45–2.65 m (6H, 4′-H_2, 4-H_2, 6-H_2); 2.88 d (4H, 2-H_2, 8-H_2, J = 7 Hz); 3.35 t (1H, 2′-H, J = 7 Hz); 3.6 m (2H, 3-H, 7-H); 6.0 d (1H, 10-H, J_{HF} = 19 Hz); 8.0 s (4H, OH). ^{13}C NMR spectrum (D_2O), δ_C, ppm: 177.8 ($C^{1'}$); 163.49 (C^{12}, J_{CF} = 19 Hz); 150.19 (C^{13}); 129.26 (C^{11}, J_{CF} = 251 Hz); 123.10 (C^{10}, J_{CF} = 21 Hz); 69.18 ($C^{2'}$); 66.09 (C^3); 65.52 (C^7); 56.98 (C^4); 56.67 (C^6); 47.27 (C^2, C^8); 32.87 ($C^{3'}$); 25.75 ($C^{4'}$); 17.50 ($C^{5'}$);

15.50 (10-CH_3). Found, %: C 40.10; H 6.80; F 3.85; N 9.00; S 6.85. $C_{15}H_{22}FN_3O_6S \cdot 3H_2O$. Calculated, %: C 40.44; H 6.34; F 4.27; N 9.43; S 7.20.

2-(3,7-Dihydroxy-10-methyl-12,13-dioxo-1,5,9-triazabicyclo[7.3.1]tridec-10-en-5-yl)-4-methylsulfinylbutanoic acid (X). To a solution of 25.4 g (0.065 mol) of compound **VI** in 50 ml of water and 50 ml of alcohol we added dropwise over a period of 30 min while cooling with water a solution of 17 g (0.079 mol) of $NaIO_4$ in 120 ml of water. The mixture was stirred for 4 h at room temperature and was left overnight. The crystals of $NaIO_3$ were filtered off, the solvent was distilled off from the filtrate, and the residue was extracted with chloroform. The extract was washed with water (2×10 ml) and evaporated to obtain 15.0 g (42%) of compound **X**, readily soluble in water and alcohol and insoluble in acetone, chloroform, and hexane. IR spectrum, ν, cm^{-1}: 640, 690 (C–S); 1040–1070 (S=O); 1080–1280 (=N–); 1340, 1400 ($RSCH_3$); 1652, 1720 (C=O, =N–C=O); 2468 ($\overset{+}{N}H$); 3286, 3600 (OH). ^{1}H NMR spectrum (D_2O), δ, ppm: 1.3–1.45 m (2H, 3′-H_2); 2.04 s (3H, 10-CH_3); 2.41 s (3H, CH_3S); 2.45–2.65 m (6H, 4′-H_2, 4-H_2, 6-H_2); 2.88 d (4H, 2-H_2, 8-H_2, J = 7 Hz); 3.35 t (1H, 2′-H, J = 7 Hz); 3.6 m (2H, 3-H, 7-H); 5.68 s (1H, 11-H); 7.15 s (3H, OH). ^{13}C NMR spectrum (D_2O), δ, ppm: 177.0 ($C^{1'}$); 162.4 (C^{12}); 157.66 (C^{13}); 151.5 (C^{10}); 98.5 (C^{11}); 69.8 ($C^{2'}$); 66.7 (C^3, C^7); 56.5 (C^4, C^6); 49.7 ($C^{4'}$); 47.8 (C^2, C^8); 39.0 ($C^{5'}$); 22.5 ($C^{3'}$); 14.65 (10-CH_3). Found, %: C 34.5; H 7.8; N 7.4; S 5.9. $C_{16}H_{25}N_3O_7S \cdot 8H_2O$. Calculated, %: C 35.10; H 7.55; N 7.67; S 5.85.

2-(3,7-Dihydroxy-12,13-dioxo-1,5,9-triazabicyclo[7.3.1]tridec-10-en-5-yl)-4-methylsulfinylbutanoic acid (IX), 2-(3,7,11-trihydroxy-10-methyl-12,13-dioxo-1,5,9-triazabicyclo[7.3.1]tridec-10-en-5-yl)-4-methylsulfinylbutanoic acid (XI), and 2-(11-fluoro-3,7-dihydroxy-12,13-dioxo-1,5,9-triazabicyclo[7.3.1]tridec-10-en-5-yl)-4-methylsulfinylbutanoic acid (XII) were synthesized as described above for compound **X**; acids **IX**, **XI**, and **XII** were isolated as yellow thick liquids.

Compound **IX**. IR spectrum, ν, cm^{-1}: 650, 690 (C–S); 1040–1080 (S=O); 1080–1280 (=N–); 1324, 1400 ($RSCH_3$); 1652, 1710 (C=C, C=O, =N–C=O); 2468 ($\overset{+}{N}H$); 1130, 1200, 3286, 3600 (OH). ^{1}H NMR spectrum (D_2O), δ, ppm: 1.3–1.6 m (2H, 3′-H_2); 2.48 s (3H, CH_3S); 2.6–2.8 m (6H, 4′-H_2, 4-H_2, 6-H_2); 3.0 d (2H, 2-H_2, J = 6.1 Hz); 3.5 t (1H, 2′-H, J = 6.6 Hz); 3.6 m (2H, 3-H, 7-H); 3.8 d (2H, 8-H_2, J = 6 Hz); 5.8 d (1H, 11-H, J = 7.3 Hz); 7.15 s (3H, OH); 8.0 d (1H, 10-H, J = 7.3 Hz). ^{13}C NMR spectrum (D_2O), δ_C, ppm: 176.8 ($C^{1'}$); 162.4 (C^{12}); 151.0 (C^{13}); 144.66 (C^{10}); 102.4 (C^{11}); 69.4 ($C^{2'}$); 67 (C^3, C^7); 56.5 (C^4, C^6); 51.5 (C^8); 49.7 ($C^{4'}$); 47.5 (C^2); 39.0 ($C^{5'}$); 22.5 ($C^{3'}$). Found, %: C 40.25; H 7.00; N 9.15; S 7.00. $C_{15}H_{23}N_3O_7S \cdot 3H_2O$. Calculated, %: C 40.63; H 6.59; N 9.48; S 7.23.

Compound **XI**. IR spectrum, ν, cm^{-1}: 660, 720 (C–S); 1050–1070 (S=O); 1090–1250 (=N–); 1330, 1370 ($\delta_s CH_3$); 1460, 1600, 1660, 1715 (C=O, =N–C=O); 3360, 3430, 3500 (OH). ^{1}H NMR spectrum (D_2O), δ, ppm: 1.37 q (2H, 3′-H_2, J = 6.5 Hz); 2.24 s (3H, 10-CH_3); 2.48 s (3H, CH_3S); 2.5–2.65 m (6H, 4′-H_2, 4-H_2, 6-H_2); 2.88 d (4H, 2-H_2, 8-H_2, J = 7 Hz); 3.35 t (1H, 2′-H, J = 6.5 Hz); 3.6 m (2H, 3-H, 7-H); 8.0 s (4H, OH). ^{13}C NMR spectrum (D_2O), δ, ppm: 177.0 ($C^{1'}$); 163.4 (C^{12}); 151,5 (C^{13}); 142.00 (C^{10}); 129.0 (C^{11}); 69.8 ($C^{2'}$); 66.7 (C^3, C^7); 56.5 (C^4, C^6); 49.7 ($C^{4'}$); 47.8 (C^2, C^8); 39.0 ($C^{5'}$); 22.5 ($C^{3'}$); 12.55 (10-CH_3). Found, %: C 42.00; H 6.80; N 8.89; S 6.62. $C_{16}H_{25}N_3O_8S \cdot 2H_2O$. Calculated, %: C 42.19; H 6.42; N 9.23; S 7.04.

Compound **XII**. IR spectrum, ν, cm^{-1}: 670, 720 (CS); 1050–1080 (S=O); 1090–1250 (=N–); 1340, 1370 ($\delta_s CH_3$); 1460, 1640, 1660, 1720 (C=O, =N–C=O); 3340, 3430, 3500 (OH). ^{1}H NMR spectrum (D_2O), δ, ppm: 1.3–1.45 m (2H, 3′-H_2); 2.11 s (3H, CH_3S); 2.45–2.65 m (6H, 4′-H_2, 4-H_2, 6-H_2); 2.88 d (4H, 2-H_2, 8-H_2, J = 7 Hz); 3.35 t (1H, 2′-H, J = 7 Hz); 3.6 m (2H, 3-H, 7-H); 7.48 d (1H, 10-H, J_{HF} = 8 Hz); 7.15 s (3H, OH). ^{13}C NMR spectrum (D_2O), ν, ppm: 178.0 ($C^{1'}$); 162.4 (C^{12}, J_{CF} = 19 Hz); 151.5 (C^{13}); 139.0 (C^{11}, J_{CF} = 249 Hz); 131.00 (C^{10}, J_{CF} = 20 Hz); 67.0 (C^7); 66.8 ($C^{2'}$); 66.5 (C^3); 56.5 (C^4, C^6); 49.7 ($C^{4'}$); 47.8 (C^2, C^8); 39.0 ($C^{5'}$); 22.5 ($C^{3'}$). Found, %: C 38.85; H 6.00; F 3.71; N 9.80; S 6.52. $C_{15}H_{22}FN_3O_7S \cdot 3H_2O$. Calculated, %: C 39.05; H 6.12; F 4.12; N 10.15; S 6.94.

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