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Recyclization of Ethyl 1-Alkyl-5-benzoyl-6-methylsulfanyl-2-oxo-1,2-dihydropyridine-3-carboxylates into Bicyclic *N*-Alkyl-5-benzoyl-2-oxo-1,2-dihydropyridine-3-carboxamide Derivatives by the Action of Nitrogen-Containing 1,4- and 1,5-Binucleophiles

V. N. Britsun, A. N. Esipenko, A. V. Gutov, A. N. Chernega, and M. O. Lozinskii

Institute of Organic Chemistry, National Academy of Sciences of Ukraine, ul. Murmanskaya 5, Kiev, 02660 Ukraine
e-mail: bvn1967@rambler.ru

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Abstract—Reactions of ethyl 1-alkyl-5-benzoyl-6-methylsulfanyl-2-oxo-1,2-dihydropyridine-3-carboxylates with nitrogen-containing 1,4- and 1,5-binucleophiles (*o*-phenylenediamine, *o*-aminobenzenethiol, ethane-1,2-diamine, and propane-1,3-diamine) involved recyclization, leading to the formation of fused *N*-alkyl-5-benzoyl-2-oxo-1,2-dihydropyridine-3-carboxamides, diethyl 6,6′-oxybis(1-alkyl-5-benzoyl-2-oxo-1,2-dihydropyridine-3-carboxylates), and diethyl 6,6′-[ethane-1,2-diyl(or propane-1,3-diyl)diimino]bis(1-alkyl-5-benzoyl-2-oxo-1,2-dihydropyridine-3-carboxylates), depending on the reactant ratio. The sequence of formation of intermediate recyclization products was determined.

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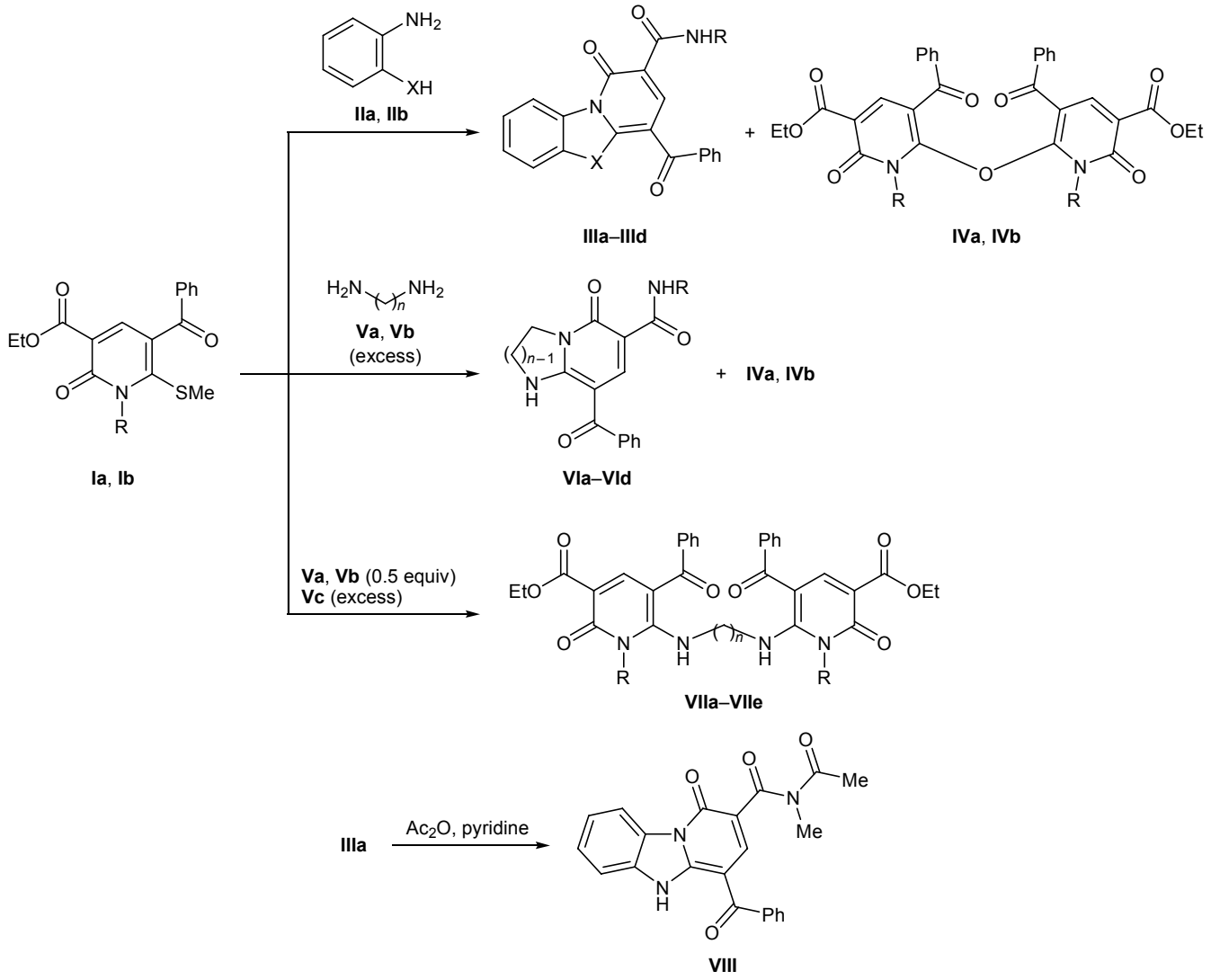
We recently developed a procedure for the synthesis of ethyl 1-alkyl-5-benzoyl-6-methylsulfanyl-2-oxo-1,2-dihydropyridine-3-carboxylates **Ia** and **Ib** [1]. Unlike methods reported previously [2–4], the developed procedure ensures high selectivity and utilizes accessible initial compounds. 2-Oxo-1,2-dihydropyridines **I** were used as substrates in cyclocondensations with nitrogen-containing 1,2-, 1,3-, and 1,5-binucleophiles [1, 2, 5]. The reactions of dihydropyridines **Ia** and **Ib** with propane-1,3-diamine involved recyclization [5].

The goal of the present work was to estimate the scope of application of the above recyclization and examine how the ratio of initial 1,2-dihydropyridin-2-one **Ia** or **Ib** and difunctional nucleophile [*o*-phenylenediamine (**IIa**), *o*-aminobenzenethiol (**IIb**), ethane-1,2-diamine (**Va**), and propane-1,3-diamine (**Vb**)] affects the reaction direction. We were also interested in elucidating the reaction mechanism (i.e., the transformation sequence and structure of intermediate products) and unambiguously determining the structure of recyclization products. Recyclizations with participation of *o*-phenylenediamine (**IIa**) and *o*-aminobenzenethiol (**IIb**), leading to the formation of benzimidazole, quinoxaline, and 1,4-benzothiazine derivatives, were the subjects of recent publications [6–8], which demonstrated increased interest in such reactions.

Compounds **Ia** and **Ib** were found to react with nucleophiles **IIa**, **IIb**, **Va**, and **Vb** along two pathways. When the reactant ratio was 1:1 or 1:2, the products were not substituted 2*H*-pyran-2-ones (as we presumed previuously [5]) but mixtures of fused *N*-alkyl-5-benzoyl-2-oxo-1,2-dihydropyridine-3-carboxamide derivatives **IIIa**–**IIId** or **VIa**–**VId** and diethyl 6,6′-oxybis(1-alkyl-5-benzoyl-2-oxo-1,2-dihydropyridine-3-carboxylates) **IVa** and **IVb**. The yields of compounds **IIIa**–**IIId**, **VIa**–**VId**, and **IVa**, **IVb** were 57–70, 39–69, and 24–49%. respectively. The reactions of compounds **Ia** and **Ib** with diamines **Va** and **Vb** at a ratio of 2:1 led to the formation of the corresponding diethyl 6,6′-[ethane-1,2-diyl(or propane-1,3-diyl)diimino]bis(1-alkyl-5-benzoyl-2-oxo-1,2-dihydropyridine-3-carboxylates) **VIIa**–**VIId** (Scheme 1). Dihydropyridine **Ia** reacted with butane-1,4-diamine (**Vc**) to give 6,6′-(butane-1,4-diyldiimino)bis(1-alkyl-5-benzoyl-2-oxo-1,2-dihydropyridine-3-carboxylate) (**VIIe**) as the only product even when the amount of diamine **Vc** was 3 equiv. Presumably, recyclization of *N*,*N*′-disubstituted 1,4-diaminobutane **VIIe** into 1,3-diazepine derivative does not occur because of difficult closure of seven-membered ring.

Fused pyridobenzimidazoles **IIIa** and **IIIb**, pyridobenzothiazoles **IIIc** and **IIId**, imidazopyridines **VIa**

Scheme 1.



I, **IV**, R = Me (**a**), Et (**b**); **II**, X = NH (**a**), S (**b**); **III**, **VI**, **VII**, R = Me (**a**, **c**), Et (**b**, **d**); **III**, X = NH (**a**, **b**), S (**c**, **d**); **V**, *n* = 2 (**a**), 3 (**b**), 4 (**c**); **VI**, **VII**, *n* = 2 (**a**, **b**), 3 (**c**, **d**), 4 (**e**)..

and **VIb**, and pyridopyrimidines **VIc** and **VId** are yellowish high-melting substances that are poorly soluble in polar organic solvents. Their structure was confirmed by IR and ^{1}H and ^{13}C NMR spectra, as well as by the transformation of compound **IIIa** into *N*-acetyl-4-benzoyl-1-oxo-1,5-dihydropyrido[1,2-*a*]benzimidazole-2-carboxamide (**VIII**) by the action of acetic anhydride in pyridine (Scheme 1).

Compounds **IIIa**–**IIId** and **VIa**–**VId** characteristically showed in the ^{1}H NMR spectra a doublet signal from methyl protons in the CH_3NH groups (**IIIa**, **IIIc**, **VIa**, **VIc**; δ 2.75–2.85 ppm, J = 2.7–4.5 Hz), a broadened singlet from the amide AlkN**H** proton (δ 8.90–9.15 ppm), a multiplet from 6-H (**IIIa**–**IIId**, δ 8.70–9.24 ppm), and a singlet from the endocyclic NH group (the position of the latter signal depended on the heteroring nature). The presence of benzoyl groups in molecules **IIIa**–**IIId**, **IVa**, **IVb**, **VIa**–**VId**, and **VIIa**–**VIIe** clearly followed from the ^{13}C NMR spectra of **IIIa**, **IVa**, **VIb**, and **VIIa**–**VIIc**, which, as well as the spectra of initial compounds **Ia** and **Ib** [1], contained a signal at δ_C 191.0–193.2 ppm typical of carbonyl carbon atom in benzoyl group.

The molecular and crystalline structures of diethyl 6,6′-(ethane-1,2-diyldiimino)bis(5-benzoyl-1-methyl-2-oxo-1,2-dihydropyridine-3-carboxylate) (**VIIa**) and 6,6′-(propane-1,3-diyldiimino)bis(5-benzoyl-1-methyl-2-oxo-1,2-dihydropyridine-3-carboxylate) (**VIIc**) were

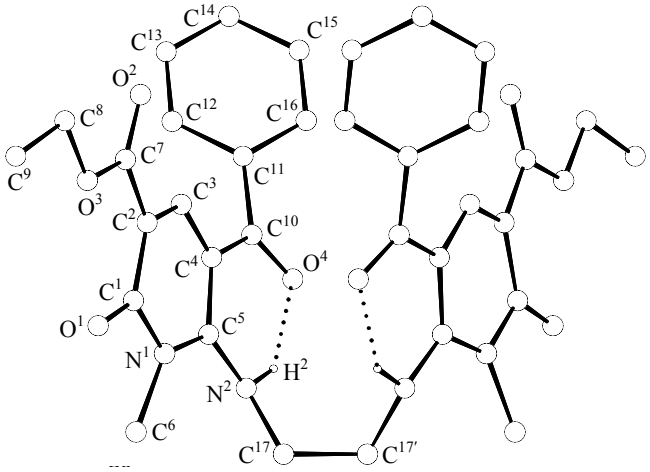


Fig. 1. Structure of the molecule of diethyl 6,6′-(ethane-1,2-diyldiimino)bis(5-benzoyl-1-methyl-2-oxo-1,2-dihydropyridine-3-carboxylate) (**VIIa**) according to the X-ray diffraction data. Intramolecular hydrogen bonds are shown with dotted lines. Atoms related to the initial ones through the *2* axis are denoted with primed numbers. Principal bond lengths (Å) and bond angles (deg): C^1–O^1 1.214(2), C^1–N^1 1.426(2), C^1–C^2 1.439(3), C^2–C^3 1.366(3), C^3–C^4 1.396(3), C^4–C^5 1.421(2), C^4–C^{10} 1.462(3), C^5–N^1 1.359(2), C^5–N^2 1.333(2), N^2–C^{17} 1.463(3), C^{17}–$C^{17'}$ 1.516(4); $C^1N^1C^5$ 124.3(2), $C^5N^2C^{17}$ 125.9(3).

determined by X-ray analysis. The structure of molecule **VIIa** and its principal geometric parameters are given in Fig. 1. Molecule **VIIa** is symmetric; it is extended along the crystallographic *2* axis. It is unusual and interesting that the central ethanediamine fragment adopts clearly unfavorable synclinal conformation (Fig. 2): the torsion angle $N^2C^{17}C^{17'}N^{2'}$ is 63.8°, and the interatomic distance $N^2\cdots N^{2'}$ is 2.910(2) Å (cf. the double van der Waals radius of the nitrogen atom 3.0 Å). The $N^1C^1C^2C^3C^4C^5$ ring is slightly nonplanar: deviations of atoms from the corresponding mean-square plane reach 0.078 Å). The N^1 atom is characterized by planar–trigonal bond configuration, whereas the configuration of the N^2 atom is an appreciably flattened *pyramid* (the sums of the bond angles at N^1 and N^2 are 359.6 and 349.5°, respectively). Effective conjugation between the lone electron pairs on N^1 and N^2 with π-electron system of the C^4=C^5 bond induces considerable shortening of formally single N^1–C^5 and N^2–C^5 bonds [1.359(2) and 1.333(2) Å, respectively] against the distance 1.43–1.45 Å typical of purely single N_{sp^2}–C_{sp^2} bond [9, 10]. The dihedral angle between the N^1C^1–C^5 and C^{11}–C^{16} ring planes is 53.5°. One more specificity of the molecular structure of compound **VIIa** is formation of a quite strong [11] intramolecular hydrogen bond $N^2H^2\cdots O^4$ [O···N 2.631(2), O···H 1.87(3) Å; ∠OHN 143(2)°] closing six-membered $N^2C^5C^4C^{10}O^4H^2$ ring. Molecules **VIIa** in crystal are arranged to form infinite stacks (Fig. 3), and neither inside the stacks nor between them shortened intermolecular contacts are observed.

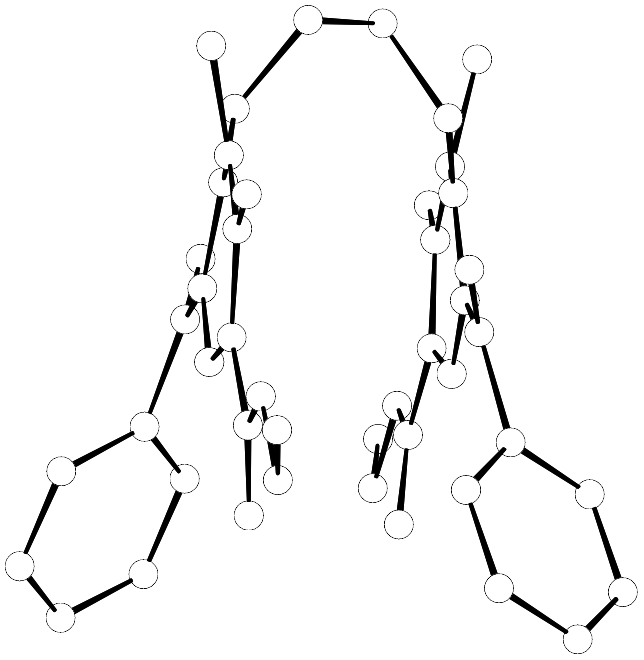


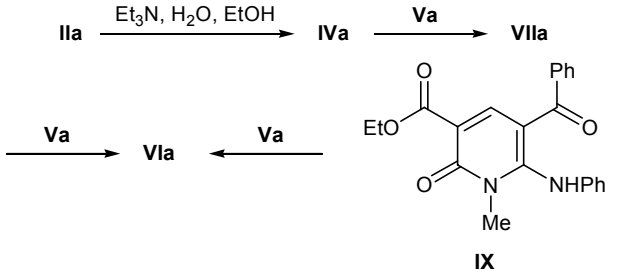
Fig. 2. A projection demonstrating synclinal conformation of the central ethylene fragment in molecule **VIIa**.

The structure of molecule **VIIc** and its principal geometric parameters are presented in Fig. 4. Extension of the $(CH_2)_n$ central bridging fragment from n = 2 in molecule **VIIa** to n = 3 in **VIIc** (i.e., increase of the distance between the dihydropyridine fragments) considerably changes the molecular conformation: the torsion angles $N^2C^{17}C^{18}C^{19}$ and $N^4C^{19}C^{18}C^{17}$ are –158.7 and 178.6°, respectively. The dihydropyridine rings N^2C^1–C^5 and N^3C^{20}–C^{24} are almost planar (deviations of atoms from the corresponding mean-square planes do not exceed 0.010 and 0.028 Å, respectively. The bond configurations at the N^1, N^2, N^3, and N^4 approach planar–trigonal (the sums of the bond angles at these nitrogen atoms range from 355.5 to 359.9°). Effective conjugation between lone electron pairs on the N^1, N^2, N^3, and N^4 atoms, on the one hand, and π-electron systems of the C^4=C^5 and C^{20}=C^{24} bonds is observed: the N^1–C^5 [1.380(5) Å], N^2–C^5 [1.336(5) Å], N^3–C^{20} [1.363(5) Å], and N^4–C^{20} bonds [1.352(5) Å] are appreciably shorter than standard purely single N_{sp^2}–C_{sp^3} bond (1.43–1.45 Å) [9, 10]. Like compound **VIIa**, molecules **VIIc** in crystal are characterized by strong intramolecular hydrogen bond N^4–$H^4\cdots O^8$ with the following parameters: O···N 2.651(5), O···H

1.99(5) Å; ∠OHN 141(5)°; as a result, six-membered H-chelate ring $N^4C^{20}C^{24}C^{29}O^8H^4$ is formed. Molecules **VIIc** in crystal are linked through medium-strength intermolecular hydrogen bonds $N^2–H^2\cdots O^1$ [O···N 2.905(5), O···H 2.02(3) Å; ∠OHN 142(5)°] to form zigzag chains as shown in Fig. 5. Thus compounds **VIIa** and **VIIc** are characterized by considerably different molecular structures and crystal packings.

Some model reactions were performed to elucidate the transformation sequence leading to compounds **IIIa**–**IIId**, **IVa**, **IVb**, **VIa**–**VId**, and **VIIa**–**VIIe** (Scheme 2). Hydrolysis of 1,2-dihydropyridin-2-one **Ia** by the action of an aqueous–alcoholic solution of triethylamine was accompanied by elimination of the methylsulfanyl group, and the product was dipyridyl ether **IVa**. The latter readily reacted with ethane-1,2-diamine (**Va**) to give compound **VIIa** in 83% yield, and the reaction of **VIIa** with excess diamine **Va** afforded 81% of *N*-methyl-8-benzoyl-5-oxo-1,2,3,5-tetrahydroimidazo[1,2-*a*]pyridine-6-carboxamide (**VIa**). Compound **VIa** was also synthesized by reaction of ethyl 5-benzoyl-1-methyl-2-oxo-6-phenylamino-1,2-dihydropyridine-3-carboxylate (**IX**) with diamine **Va**, but the yield did not exceed 47%. We can conclude that high thermodynamic stability of fused heterocycles **VIa**–**VId** also favors the observed recyclization.

Scheme 2.



The above experimental data led us to propose the following recyclization mechanism (Scheme 3). Presumably, the first step is hydrolysis or aminolysis of dihydropyridines **Ia** and **Ib** with formation of compounds **IVa** and **IVb** or intermediates **XIa**–**XId**, respectively. Hydrolysis products **IVa** and **IVb** are also capable of undergoing aminolysis by the action of diamines **Va** and **Vb** to give the same intermediates **XIa**–**XId**. Itramolecular transamination of **XIa**–**XId** with opening of the pyridine ring leads to dihydroimidazole (tetrahydropyrimidine) derivatives **XIIa**–**XIId** which undergo isomerization at the double C=C bond to adopt conformation **XIIIa**–**XIIId** which is the most favorable for subsequent intramolecular cyclization to fused 3-alkylcarbamoyl-5-benzoylpyridin-2-one derivatives **VIa**–**VId**.

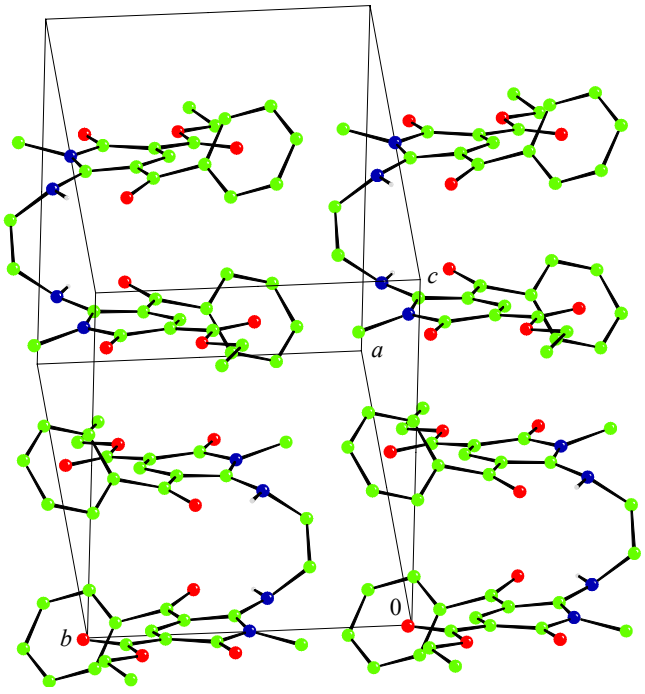


Fig. 3. Packing of molecules **VIIa** in crystal.

Unlike reactions of ethyl 5-cyano-4-methyl-2-methylsulfanyl-6-oxo-1-phenyl-1,6-dihydropyridine-3-carboxylate with ethane-1,2-diamine and propane-1,3-

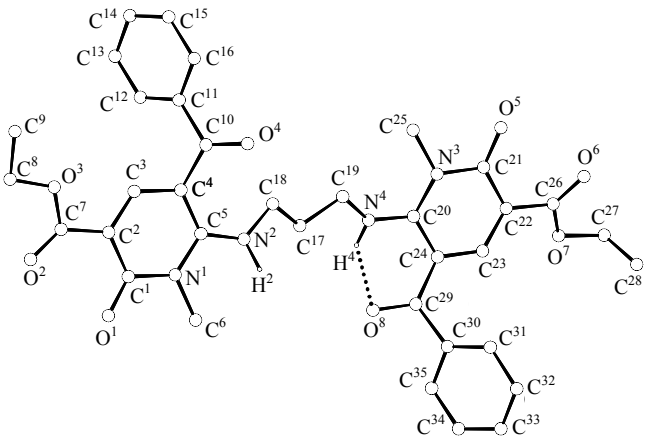
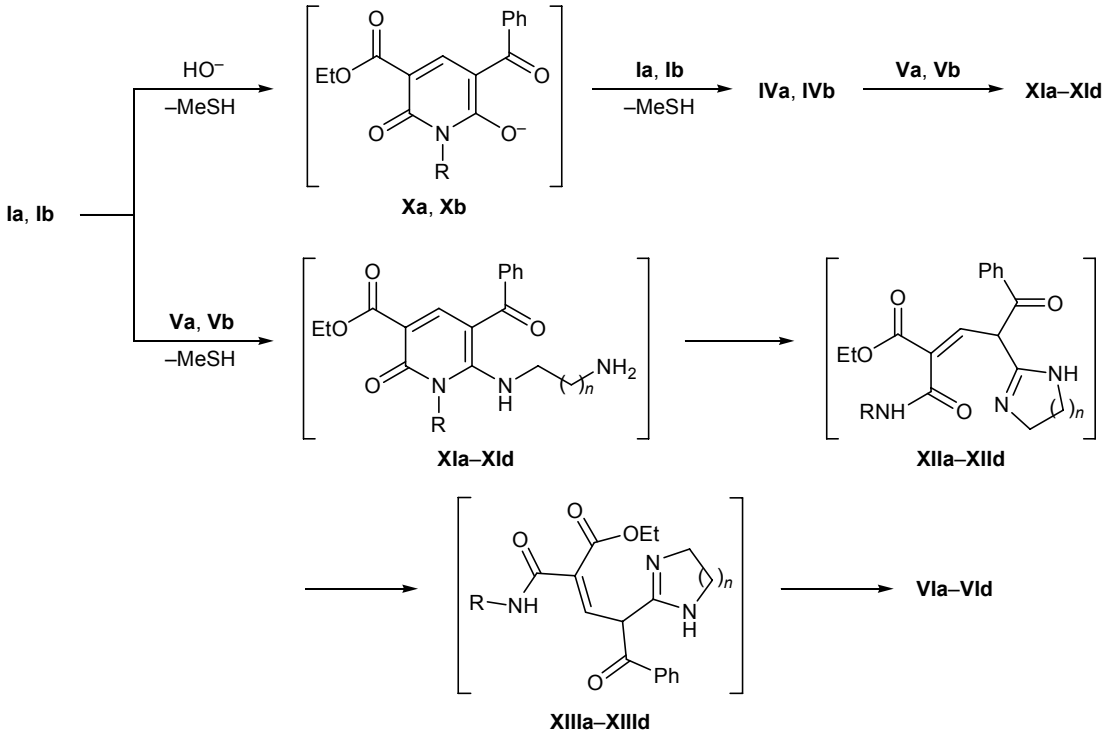


Fig. 4. Structure of the molecule of diethyl 6,6′-(propane-1,3-diyldiimino)bis(5-benzoyl-1-methyl-2-oxo-1,2-dihydropyridine-3-carboxylate) (**VIIc**) according to the X-ray diffraction data. Intramolecular hydrogen bonds are shown with dotted lines. Principal bond lengths (Å) and bond angles (deg): $O^1–C^1$ 1.242(5), $N^1–C^1$ 1.411(5), $N^1–C^5$ 1.380(5), $N^2–C^5$ 1.336(5), $N^2–C^{17}$ 1.433(5), $O^5–C^{21}$ 1.228(5), $N^3–C^{20}$ 1.363(5), $N^3–C^{21}$ 1.424(5), $N^4–C^{19}$ 1.481(5), $N^4–C^{20}$ 1.352(5); $C^1N^1C^5$ 124.5(3), $C^5N^2C^{17}$ 128.0(4), $C^{20}N^3C^{21}$ 123.8(3), $C^{19}N^3C^{20}$ 132.0(4).

Scheme 3.



diamine, reported previously [12], the described recyclization of ethyl 1-alkyl-5-benzoyl-6-methylsulfanyl-2-oxo-1,2-dihydropyridine-3-carboxylates involves the ethoxycarbonyl group in the substrate, while no elimination of the alkylamino group occurs, so that the process is possible only via cleavage of the N–C[6] bond in the pyridine ring. As a result, bicyclic 5-benzoylpyridin-2-one derivatives having a carboxamide functionality can be obtained.

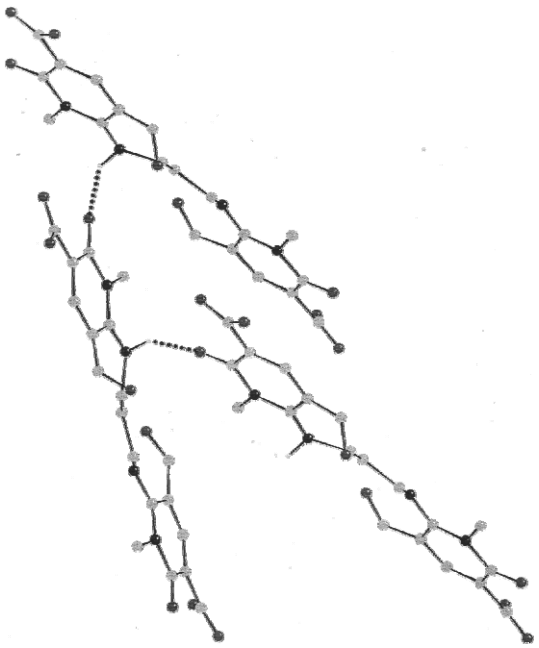


Fig. 5. A fragment of crystal packing of compound **VIIc** (phenyl and ethyl substituents are not shown).

Thus the examined recyclization of ethyl 1-alkyl-5-benzoyl-6-methylsulfanyl-2-oxo-1,2-dihydropyridine-3-carboxylates is general, and it provides a new synthetic route to previously unknown fused 3-alkylcarbamoyl-5-benzoylpyridin-2(1*H*)-one derivatives.

EXPERIMENTAL

The ^{1}H and ^{13}C NMR spectra were recorded on a Varian Unity 300 spectrometer at 300 and 75 MHz, respectively, using DMSO-d_6 as solvent and tetramethylsilane as internal reference. The IR spectra were measured in KBr on a UR-20 instrument. Ethyl 5-benzoyl-1-methyl-2-oxo-6-phenylamino-1,2-dihydropyridine-3-carboxylate (**IX**) was synthesized according to the procedure described in [1].

The principal crystallographic parameters of compounds **VIIa** and **VIIc** and details of the X-ray diffraction data acquisition and structure solution and refinement are collected in table. The structures of both com-

pounds were solved by the direct method and were refined by the least-squares procedure in full-matrix anisotropic approximation using CRYSTALS software package [13]. All hydrogen atoms were visualized by difference syntheses of electron density and were involved in the refinement procedure with fixed positional and thermal parameters. The positions of the H^2 atom in molecule **VIIa** and of H^2 and H^4 in **VIIc** (these hydrogen atoms participate in H bonding) were refined in isotropic approximation. Chebyshev's weight scheme was applied [14]. The complete sets of crystallographic data for compounds **VIIa** and **VIIc** were deposited to the Cambridge Crystallographic Data Centre (entry nos. CCDC 671856 and CCDC 710260).

Recyclization of ethyl 1-alkyl-5-benzoyl-6-methylsulfanyl-2-oxo-1,2-dihydropyridine-3-carboxylates Ia and Ib (*general procedure***).** A solution of 1 mmol of 1,2-dihydropyridin-2-one **Ia** or **Ib** and 1.0 mmol of amine **IIa** or **IIb** (or 1.5 mmol of diamine **Va** or **Vb**) in 4 ml of propan-2-ol was heated for 2–6 h under reflux. The mixture was cooled, and the precipitate of compound **IIIa**–**IIId** or **VIa**–**VId** was filtered off. Dipyridyl ether **IVa** or **IVb** was isolated by evaporation of the filtrate.

4-Benzoyl-*N*-methyl-1-oxo-1,5-dihydropyrido[1,2-*a*]benzimidazole-2-carboxamide (IIIa). Yield 70%, mp 283–285°C (from DMSO). IR spectrum, ν, cm^{-1}: 3330, 3000, 1675, 1620, 1600, 1560, 1540, 1470, 1450, 1390, 1370. ^1H NMR spectrum, δ, ppm: 2.85 d (3H, NHC**H**$_3$, J = 3.6 Hz), 7.48 m (1H, H_{arom}), 7.63–7.69 m (6H, H_{arom}), 7.84 m (1H, 6-H), 8.68 s (1H, 3-H), 8.70 m (1H, 9-H), 9.00 br.s (1H, N**H**Me), 13.71 s (1H, 5-H). ^{13}C NMR spectrum, δ_C, ppm: 25.7 (NMe), 99.4, 105.6, 113.0, 116.4, 123.5, 126.8, 126.9, 128.4, 128.5, 131.2, 131.5, 138.5, 144.1, 144.9, 159.4 (C=O), 163.8 (C=O), 191.2 (Ph**C**=O). Found, %: C 69.74; H 4.31; N 12.13. $C_{20}H_{15}N_3O_3$. Calculated, %: C 69.56; H 4.38; N 12.17.

4-Benzoyl-*N*-ethyl-1-oxo-1,5-dihydropyrido[1,2-*a*]benzimidazole-2-carboxamide (IIIb). Yield 63%, mp 272–275°C (from DMSO). IR spectrum, ν, cm^{-1}: 3330, 3000, 1685, 1610, 1560, 1470, 1440, 1390, 1370, 1340, 1320, 1260. ^1H NMR spectrum, δ, ppm: 1.16 t (3H, CH_2C**H**$_3$, J = 6.3 Hz), 3.36 m (2H, NHC**H**$_2$), 7.49 m (1H, H_{arom}), 7.62–7.76 m (6H, H_{arom}), 7.88 m (1H, 6-H), 8.69 s (1H, 3-H), 8.71 m (1H, 9-H), 9.11 br.s (1H, N**H**Et), 13.73 s (1H, 5-H). Found, %: C 69.89; H 4.56; N 11.85. $C_{21}H_{17}N_3O_3$. Calculated, %: C 70.18; H 4.77; N 11.69.

Principal crystallographic parameters of compounds **VIIa** and **VIIc**

Parameter	**VIIa**	**VIIc**
Diffractometer	Bruker Smart ApexII	
Irradiation	MoK_α	
Scan range	$-30 \le h \le 33$	$-14 \le h \le 14$
	$-11 \le k \le 11$	$-11 \le k \le 14$
	$-2334 \le l \le 8$	$-15 \le l \le 12$
θ_{max}, deg	28.7	26.4
Crystal habit, mm	0.25×0.30×0.51	0.19×0.40×0.47
Crystal system	Monoclinic	Monoclinic
Space group	$C2/c$	Pc
a, Å	26.396(3)	12.2098(9)
b, Å	8.8113(7)	11.4144(8)
c, Å	17.614(2)	12.0720(8)
β, deg	131.58(2)	108.732(2)
V, Å^3	3064.5(7)	1593.3(2)
Z	8	2
d_{calc}, g/cm^3	1.36	1.33
μ, cm^{-1}	0.98	0.96
F(000)	1320	624
Total number of reflections	6984	9303
Number of independent reflections	3689	4484
Number of reflections with $I \ge 3\sigma(I)$	2048	3261
R_{merge}	0.02	0.01
R_1 (F)	0.044	0.044
R_w (F)	0.047	0.046
Goodness of fit	1.077	1.209
Weight coefficients	0.23, –0.12, –0.11, –0.16	1.28, –0.70, 1.14, –0.30, 0.28
Residual electron density, max/min, e/cm^3	0.23/–0.20	0.60/–0.41

4-Benzoyl-*N*-methyl-1-oxo-1*H*-pyrido[2,1-*b*][1,3]benzothiazole-2-carboxamide (IIIc). Yield 61%, mp 250–252°C (from DMSO). IR spectrum, ν, cm^{-1}: 3350, 3000, 1670, 1615, 1560, 1490, 1460, 1420, 1380, 1330. ^1H NMR spectrum, δ, ppm: 2.87 d (3H, NHC**H**$_3$, J = 2.7 Hz), 7.66 m (7H, H_{arom}), 8.23 m (1H, 6-H), 8.74 s (1H, 3-H), 9.02 br.s (1H, N**H**CH_3), 9.20 m (1H, 9-H). Found, %: C 66.02; H 4.15; N 7.48; S 8.64. $C_{20}H_{14}N_2O_3S$. Calculated, %: C 66.29; H 3.89; N 7.73; S 8.85.

4-Benzoyl-*N*-ethyl-1-oxo-1*H*-pyrido[2,1-*b*][1,3]-benzothiazole-2-carboxamide (IIId). Yield 57%, mp 241–243°C (from DMSO). IR spectrum, ν, cm^{-1}: 3300, 3000, 1690, 1620, 1570, 1500, 1470, 1385, 1310. ^{1}H NMR spectrum, δ, ppm: 1.18 t (3H, $CH_2C\mathbf{H}_3$, J = 6.6 Hz), 3.34 m (2H, $NHC\mathbf{H}_2$), 7.68–7.83 m (7H, H_{arom}), 8.26 m (1H, 6-H), 8.78 s (1H, 3-H), 9.15 br.s (1H, N**H**Et), 9.24 m (1H, 9-H). Found, %: C 66.73; H 4.42; N 7.29; S 8.40. $C_{21}H_{16}N_2O_3S$. Calculated, %: C 67.01; H 4.28; N 7.44; S 8.52.

8-Benzoyl-*N*-methyl-5-oxo-1,2,3,5-tetrahydroimidazo[1,2-*a*]pyridine-6-carboxamide (VIa). Yield 69%, mp 335–337°C (from DMSO). IR spectrum, ν, cm^{-1}: 3380, 3300, 3050, 2970, 1680, 1640, 1600, 1580, 1500. ^{1}H NMR spectrum, δ, ppm: 2.75 d (3H, $NHC\mathbf{H}_3$, J = 4.2 Hz), 3.91 m (2H, 2-H), 4.14 t (2H, 3-H, J = 9.3 Hz), 7.52 m (5H, Ph), 8.31 s (1H, 7-H), 8.90 br.s (1H, N**H**CH_3), 9.39 br.s (1H, 1-H). Found, %: C 64.37; H 4.98; N 14.30. $C_{16}H_{15}N_3O_3$. Calculated, %: C 64.64; H 5.09; N 14.13.

8-Benzoyl-*N*-ethyl-5-oxo-1,2,3,5-tetrahydroimidazo[1,2-*a*]pyridine-6-carboxamide (VIb). Yield 63%, mp 300–303°C (from DMSO). IR spectrum, ν, cm^{-1}: 3400, 3300, 3100, 3000, 1680, 1640, 1610, 1580, 1500, 1450, 1380, 1330. ^{1}H NMR spectrum, δ, ppm: 1.08 t (3H, $CH_2C\mathbf{H}_3$, J = 7.2 Hz), 3.21 m (2H, $NHC\mathbf{H}_2$), 3.92 m (2H, 2-H), 4.13 t (2H, 3-H, J = 9.0 Hz), 7.53 m (5H, Ph), 8.32 s (1H, 7-H), 9.02 br.s (1H, N**H**Et), 9.37 br.s (1H, 1-H). ^{13}C NMR spectrum, δ_C, ppm: 14.8 ($CH_2\mathbf{C}H_3$), 33.2 (C^2), 43.1 ($\mathbf{C}H_2CH_3$), 43.4 (C^3), 97.7, 106.5, 127.8, 128.3, 130.7, 138.8, 146.4, 156.3, 160.3 (C=O), 162.8 (C=O), 191.3 (Ph**C**=O). Found, %: C 65.60; H 5.58; N 13.61. $C_{17}H_{17}N_3O_3$. Calculated, %: C 65.58; H 5.50; N 13.50.

9-Benzoyl-*N*-methyl-6-oxo-2,3,4,6-tetrahydro-1*H*-pyrido[1,2-*a*]pyrimidine-7-carboxamide (VIc). Yield 43%, mp 253–256°C (from nitromethane). IR spectrum, ν, cm^{-1}: 3300, 3100, 2950, 1670, 1640, 1590, 1550, 1510, 1440, 1400, 1380. ^{1}H NMR spectrum, δ, ppm: 2.04 br.m (2H, 3-H), 2.75 d (3H, $NHC\mathbf{H}_3$, J = 4.5 Hz), 3.52 br.m (2H, 2-H), 3.99 br.m (2H, 4-H), 7.39–7.65 m (5H, Ph), 8.31 s (1H, 8-H), 8.92 q (1H, N**H**CH_3, J = 4.5 Hz), 10.88 br.s (1H, 1-H). ^{13}C NMR spectrum, δ_C, ppm: 18.7 (C^3), 26.1 (NCH_3), 38.7 (C^2), 39.9 (C^4), 98.8, 104.6, 128.5, 128.9, 131.1, 140.0, 146.8, 155.0, 161.4 (C=O) , 164.4 (C=O), 194.1 (Ph**C**=O). Found, %: C 65.73; H 5.32; N 13.74. $C_{17}H_{17}N_3O_3$. Calculated, %: C 65.58; H 5.50; N 13.50.

9-Benzoyl-*N*-ethyl-6-oxo-2,3,4,6-tetrahydro-1*H*-pyrido[1,2-*a*]pyrimidine-7-carboxamide (VId). Yield 39%, mp 257–259°C (from nitromethane). IR spectrum, ν, cm^{-1}: 3300, 3100, 3000, 1670, 1640, 1580, 1540, 1510, 1470, 1380. ^{1}H NMR spectrum, δ, ppm: 1.07 t (3H, $CH_2C\mathbf{H}_3$, J = 6.6 Hz), 2.06 br.m (2H, 3-H), 3.47 br.m (2H, $C\mathbf{H}_2CH_3$), 3.53 br.m (2H, 2-H), 3.98 br.m (2H, 4-H), 7.40–7.61 m (5H, Ph), 8.32 s (1H, 8-H), 9.05 br.t (1H, N**H**CH_2), 10.87 br.s (1H, 1-H). Found, %: C 66.64; H 5.68; N 13.15. $C_{18}H_{19}N_3O_3$. Calculated, %: C 66.45; H 5.89; N 12.91.

Compounds IVa and IVb (*general procedure*). A solution of 1 mmol of 1,2-dihydropyridine **Ia** or **Ib** and 3 mmol of triethylamine in 3 ml of 75% aqueous ethanol was heated for 10 h under reflux. The solvent was evaporated, the oily residue was dissolved in 3 ml of water, 0.2 ml of acetic acid was added, the mixture was cooled to 5°C, and the precipitate was filtered off.

Diethyl 6,6′-oxybis(5-benzoyl-1-methyl-2-oxo-1,2-dihydropyridine-3-carboxylate) (IVa). Yield 52%, mp 100–101°C (from propan-2-ol). IR spectrum, ν, cm^{-1}: 3100, 3000, 1730, 1680, 1600, 1530, 1460, 1400, 1380, 1310. ^{1}H NMR spectrum, δ, ppm: 1.24 t (6H, $CH_2C\mathbf{H}_3$, J = 6.9 Hz), 3.29 s (6H, NCH_3), 4.19 q (4H, OCH_2, J = 6.9 Hz), 7.56–7.67 m (10H, Ph), 8.18 s (2H, 4-H). ^{13}C NMR spectrum, δ_C, ppm: 14.0 ($CH_2\mathbf{C}H_3$), 26.6 (NCH_3), 60.3 (OCH_2), 104.4 (C^4), 105.5 (C^3), 128.5, 128.8, 132.3, 135.2, 144.1 (C^5), 160.3 (C^6), 164.8 (C^2), 166.5 (CO_2Et), 191.0 (Ph**C**=O). Found, %: C 65.94; H 4.66; N 4.64. $C_{32}H_{28}N_2O_9$. Calculated, %: C 65.75; H 4.83; N 4.79.

Diethyl 6,6′-oxybis(5-benzoyl-1-ethyl-2-oxo-1,2-dihydropyridine-3-carboxylate) (IVb). Yield 45%, mp 75–77°C (from propan-2-ol). IR spectrum, ν, cm^{-1}: 3100, 3000, 1720, 1680, 1610, 1530, 1450, 1400, 1370, 1320. ^{1}H NMR spectrum, δ, ppm: 1.28 m (12H, $CH_2C\mathbf{H}_3$), 4.18 q (4H, OCH_2, J = 7.1 Hz), 4.37 q (4H, NCH_2, J = 6.4 Hz), 7.52–7.65 m (10H, Ph), 8.17 s (2H, 4-H). Found, %: C 66.43; H 4.99; N 4.86. $C_{34}H_{32}N_2O_9$. Calculated, %: C 66.66; H 5.26; N 4.57.

Compounds VIIa–VIIe (*general procedure*). A solution of 0.5 mmol of amine **Va**–**Vc** in 3 ml of propan-2-ol was added dropwise under stirring to a solution of 1 mmol of dihydropyridine **Ia** or **Ib** in 3 ml of propan-2-ol. The mixture was kept for 3 h at 20°C, and the precipitate was filtered off.

Diethyl 6,6′-(ethane-1,2-diyldiimino)bis(5-benzoyl-1-methyl-2-oxo-1,2-dihydropyridine-3-carboxylate) (VIIa). Yield 73%, mp 220–222°C (from nitromethane). IR spectrum, ν, cm^{-1}: 3400, 3200, 3050, 1720, 1680, 1580, 1540, 1500, 1660, 1440. ^{1}H NMR

spectrum, δ, ppm: 1.15 t (6H, $CH_2C\mathbf{H}_3$, J = 6.9 Hz), 3.40 s (6H, NCH_3), 3.65 br.s (4H, NCH_2), 4.07 q (4H, OCH_2, J = 6.9 Hz), 7.45–7.56 m (10H, Ph), 8.04 s (2H, 4-H), 9.34 s (2H, NH). ^{13}C NMR spectrum, δ_C, ppm: 14.7 ($CH_2\mathbf{C}H_3$), 33.4 (NCH_3), 48.0 (NCH_2), 60.1 (OCH_2), 101.5, 104.5, 128.8, 129.1, 132.0, 138.9, 148.2, 159.0, 160.2, 164.6 (C=O), 193.1 (Ph**C**=O). Found, %: C 65.32; H 5.22; N 9.07. $C_{34}H_{34}N_4O_8$. Calculated, %: C 65.17; H 5.47; N 8.94.

Diethyl 6,6′-(ethane-1,2-diyldiimino)bis(5-benzoyl-1-ethyl-2-oxo-1,2-dihydropyridine-3-carboxylate) (VIIb). Yield 69%, mp 155–158°C (from ethanol). IR spectrum, ν, cm^{-1}: 3300, 3100, 3000, 1720, 1660, 1620, 1590, 1520, 1460, 1420. ^1H NMR spectrum, δ, ppm: 1.14 m (12H, $CH_2C\mathbf{H}_3$), 3.46 br.s (4H, NCH_2), 4.05 m (8H, $C\mathbf{H}_2CH3$), 7.48–7.57 m (10H, Ph), 8.05 s (2H, 4-H), 8.76 s (2H, NH). ^{13}C NMR spectrum, δ_C, ppm: 12.8 ($NCH_2\mathbf{C}H_3$), 14.2 ($OCH_2\mathbf{C}H_3$), 37.9 ($N\mathbf{C}H_2CH_3$), 47.3 (NCH_2), 59.5 (OCH_2), 101.1, 103.6, 128.4, 128.8, 131.9, 138.1, 147.8, 157.4, 157.8, 164.2 (C=O), 191.3 (Ph**C**=O). Found, %: C 65.83; H 6.02; N 8.65. $C_{36}H_{38}N_4O_8$. Calculated, %: C 66.04; H 5.85; N 8.56.

Diethyl 6,6′-(propane-1,3-diyldiimino)bis(5-benzoyl-1-methyl-2-oxo-1,2-dihydropyridine-3-carboxylate) (VIIc). Yield 67%, mp 215–218°C (from nitromethane). IR spectrum, ν, cm^{-1}: 3400, 3200, 3000, 1720, 1660, 1580, 1520, 1450, 1370. ^1H NMR spectrum, δ, ppm: 1.15 t (6H, $CH_2C\mathbf{H}_3$, J = 7.2 Hz), 2.03 t (2H, CH_2, J = 6.6 Hz), 3.21 m (4H, NCH_2), 3.43 s (6H, NCH_3), 4.08 q (4H, OCH_2, J = 7.2 Hz), 7.44–7.61 m (10H, Ph), 8.08 s (2H, 4-H), 9.43 s (2H, NH). ^{13}C NMR spectrum, δ_C, ppm: 14.7 ($CH_2\mathbf{C}H_3$), 26.0 (CH_2), 30.0 (NCH_3), 48.0 (NCH_2), 60.1 (OCH_2), 101.5, 104.5, 128.8, 129.1, 132.0, 138.9, 148.2, 159.0, 160.2, 164.6, 193.1 (Ph**C**=O). Found, %: C 65.45; H 5.84; N 9.02. $C_{35}H_{36}N_4O_8$. Calculated, %: C 65.61; H 5.66; N 8.74.

Diethyl 6,6′-(propane-1,3-diyldiimino)bis(5-benzoyl-1-methyl-2-oxo-1,2-dihydropyridine-3-carboxylate) (VIId). Yield 62%, mp 123–125°C (from propan-2-ol). IR spectrum, ν, cm^{-1}: 3300, 3050, 3000, 1720, 1650, 1630, 1590, 1510, 1460, 1410. ^1H NMR spectrum, δ, ppm: 1.16 m (12H, $CH_2C\mathbf{H}_3$), 1.99 t (2H, CH_2, J = 6.3 Hz), 3.17 m (4H, NCH_2), 4.08 m (8H, $C\mathbf{H}_2CH_3$), 7.48–7.62 m (10H, Ph), 8.02 s (2H, 4-H), 8.89 s (2H, NH). Found, %: C 66.26; H 5.92; N 8.50. $C_{37}H_{40}N_4O_8$. Calculated, %: C 66.45; H 6.03; N 8.38.

Diethyl 6,6′-(butane-1,4-diyldiimino)bis(5-benzoyl-1-methyl-2-oxo-1,2-dihydropyridine-3-carboxylate) (VIIe). Yield 60%, mp 233–236°C (from nitromethane). IR spectrum, ν, cm^{-1}: 3100, 3000, 2900, 1720, 1680, 1570, 1600, 1500, 1470, 1450, 1410. ^1H NMR spectrum, δ, ppm: 1.15 t (6H, $CH_2C\mathbf{H}_3$, J = 7.2 Hz), 1.71 br.s (4H, CH_2), 3.48 br.s (10H, NMe, CH_2), 4.08 q (4H, OCH_2, J = 7.2 Hz), 7.42–7.65 m (10H, Ph), 8.12 s (2H, 4-H), 9.90 s (2H, NH). Found, %: C 65.76; H 6.03; N 8.69. $C_{36}H_{38}N_4O_8$. Calculated, %: C 66.04; H 5.85; N 8.56.

***N*-Acetyl-4-benzoyl-1-oxo-1,5-dihydropyrido-[1,2-*a*]benzimidazole-2-carboxamide (VIII).** A solution of 1 mmol of compound **IIIa** and 2 mmol of pyridine in 10 mmol of acetic anhydride was heated for 8 h under reflux. The mixture was cooled, and the precipitate was filtered off. Yield 75%, mp 245–247°C (from DMSO). IR spectrum, ν, cm^{-1}: 3250, 3000, 2950, 1690, 1670, 1620, 1560, 1540, 1490, 1460, 1390. ^1H NMR spectrum, δ, ppm: 2.28 s (3H, CH_3CO), 3.16 s (3H, NCH_3), 7.51 m (1H, H_{arom}), 7.55–7.72 m (6H, H_{arom}), 7.87 m (1H, 6-H), 8.18 (1H, 3-H), 8.70 (1H, 9-H), 13.78 (1H, 5-H). Found, %: C 68.06; H 4.33; N 11.09. $C_{22}H_{17}N_3O_4$. Calculated, %: C 68.21; H 4.42; N 10.85.

Recyclization of ethyl 5-benzoyl-1-methyl-2-oxo-6-phenylamino-1,2-dihydropyridine-3-carboxylate (IX) to 8-benzoyl-*N*-methyl-5-oxo-1,2,3,5-tetrahydroimidazo[1,2-*a*]pyridine-6-carboxamide (VIa). A solution of 1 mmol of dihydropyridine **IX** and 1 mmol of diamine **Va** in 3 ml of propan-2-ol was heated for 6 h under reflux. The mixture was cooled, and the precipitate was filtered off. Yield 47%.

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