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Heterocyclizations of Functionalized Heterocumulenes with C,N- and C,O-Dinucleophiles: II.* Reaction of 1-Chloro- and 1,1-Dichloroalkyl Isocyanates and 1-Chloroalkylidenecarbamates with 2-Bensothiazolylacetonitrile, 2-Benzothiazolylacetates, and Bis(2-benzothiazolyl)methane

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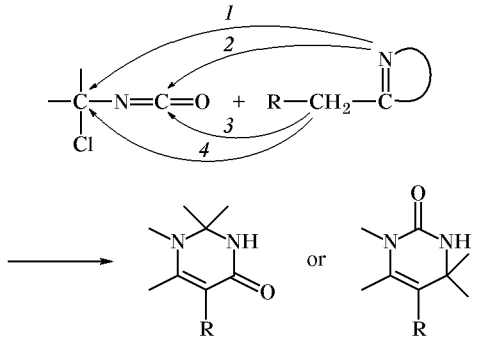
Abstract—1-Chloroalkyl isocyanates react with 2-R-methylbenzothiazoles [R = CN, C(O)OAlk, 2-benzothiazolyl] in the presence of triethylamine to give 4-R-2,3-dihydro-1*H*-pyrimido[6,1-*b*][1,3]benzothiazol-1-ones. The same reaction at elevated temperature in the absence of a base yields isomeric 4-R-2,3-dihydro-1*H*-pyrimido[6,1-*b*][1,3]benzothiazol-3-ones. 4-R-1*H*-Pyrimido[6,1-*b*][1,3]benzothiazol-1-ones are formed in the reaction of 1,1-dichloroalkyl isocyanates or methyl 1-chloroalkylidenecarbamates with 2-benzothiazolylacetonitrile or bis(2-benzothiazolyl)methane.

Derivatives of 2-benzothiazolylacetic acid, namely nitrile and esters are widely used in the chemistry of heterocyclic compounds for the synthesis of more complex fused systems, e.g., pyrrolo- [2–4] and pyridobenzothiazoles [5–8]. As concerns methods of synthesis of pyrimido[6,1-*b*][1,3]benzothiazoles [9–11], the condensation of 2-benzothiazolylacetonitrile with the only representative of functionalized heterocumulenes, benzoyl isothiocyanate, has been reported [12]. The high selectivity of this reaction, which yields exclusively 1*H*-pyrimido[6,1-*b*][1,3]benzothiazole-3-thione, prompted us to extend its scope to other functionally substituted heterocumulenes, 1-chloroalkyl isocyanates **Ia**–**Ic**, 1,1-dichloroalkyl isocyanates **Id** and **Ie**, and also their derivatives, methyl 1-chloroalkylidenecarbamates **If** and **Ig**. Apart from 2-benzothiazolylacetonitrile (**IIa**), as C,N-dinucleophilic component we used ethyl 2-benzothiazolylacetate (**IIb**), benzyl 2-benzothiazolylacetate (**IIc**), and bis(2-benzothiazolyl)methane (**IId**).

1-Chloroalkyl isocyanates **Ia**–**Ic** are highly reactive electrophilic reagents [13]. Molecules of compounds **II** contain two nucleophilic centers: nitrogen atom in the thiazole ring and 2-methylene group. The latter is activated due to the presence of two electron-acceptor substituents, and it readily loses a proton to give C-nucleophilic center [4]. Thus, four possible reaction paths shown in Scheme 1 could lead to formation of two isomeric cyclocondensation products.

Scheme 1.



We succeeded in finding conditions for selective cyclocondensations of 1-chloroalkyl isocyanates **Ia**–**Ic** with 2-substituted benzothiazoles **IIa**–**IId**, which

* For communication I, see [1].

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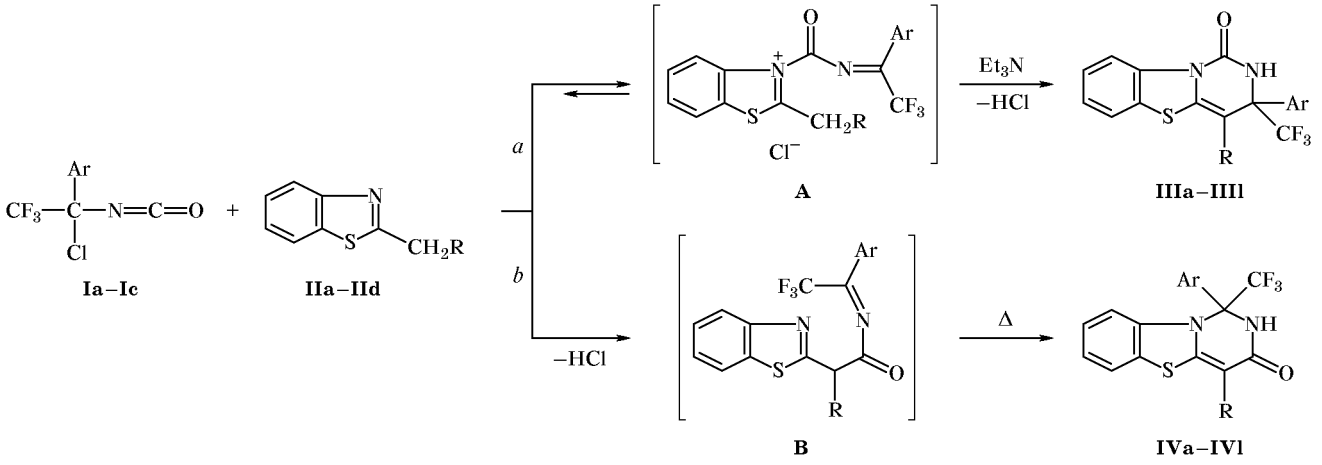
Scheme 2.



I, Ar = Ph (**a**), 4-MeC_6H_4 (**b**), 4-$MeOC_6H_4$ (**c**); **II**, R = CN (**a**), EtOC(O) (**b**), $PhCH_2OC(O)$ (**c**), 2-benzothiazolyl (**d**); **III**, **IV**, R = CN, Ar = Ph (**a**), 4-MeC_6H_4 (**b**), 4-$MeOC_6H_4$ (**c**); R = EtOC(O), Ar = Ph (**d**), 4-MeC_6H_4 (**e**), 4-$MeOC_6H_4$ (**f**); R = $PhCH_2OC(O)$, Ar = Ph (**g**), 4-MeC_6H_4 (**h**), 4-$MeOC_6H_4$ (**i**); R = 2-benzothiazolyl, Ar = Ph (**j**), 4-MeC_6H_4 (**k**), 4-$MeOC_6H_4$ (**l**).

allowed us to obtain each of the above structures. The reaction of compounds **I** with **II** in benzene in the presence of triethylamine at room temperature afforded 4-R-2,3-dihydro-1*H*-pyrimido[6,1-*b*][1,3]-benzothiazol-1-ones **IIIa**–**IIIl**. When the reaction was performed in boiling toluene in the absence of triethylamine, the products were isomeric 4-R-2,3-dihydro-1*H*-pyrimido[6,1-*b*][1,3]benzothiazol-3-ones **IVa**–**IVl** (Scheme 2). Most probably, mixing of the reactants in benzene or toluene at room temperature gives rise to equilibrium between the initial compounds and N-carbamoylation product **A**. Salt **A** readily loses proton from the methylene group by the action triethylamine (path *a*), and the subsequent intramolecular attack by the C-anionic center thus formed on the electrophilic C=N bond leads to ring closure. At elevated temperature, the equilibrium shifts toward the initial reactants (path *b*) which react according to the C-carbamoylation pattern to give intermediate **B** which then undergoes intramolecular ring closure (Scheme 2). The formation of intermediate like **B** was detected by ^{19}F NMR spectroscopy (δ_F –71.91 ppm) in the reaction of 1-chloro-2,2,2-trifluoro-1-phenylethyl isocyanate (**Ia**) with 2-benzothiazolylacetonitrile (**IIa**).

Differences in the structure of isomeric heterocycles **III** and **IV** are reflected in their IR and ^1H, ^{19}F, and ^{13}C NMR spectra (Tables 1, 2). In particular, the IR spectra of **III** characteristically contain absorption bands belonging to the endocyclic urea fragment (C=O, 1715–1725 cm^{-1}; N–H, 3220–3250 cm^{-1}), which indicate the absence of association in crystal. The lactam carbonyl absorption in the IR spectra of compounds **IV** appears as a broad band at 1660–1700 cm^{-1}, and the N–H bond gives rise to several bands in the range from 3045 to 3320 cm^{-1}. These data suggest association in crystal via intermolecular hydrogen bonding. Absorption bands due to stretching vibrations of the exocyclic carbonyl group in compounds **IIId**–**IIIi** are overlapped with those belonging to the endocyclic carbonyl group; in the spectra of **IVd**–**IVi**, the ester and lactam carbonyl groups appear as a strongly broadened absorption band.

The 9-H proton in molecules **III** suffers deshielding effect of the C^1=O carbonyl group, while the same proton in structures **IV** is shielded due to ring current in the aromatic substituent. Therefore, the range of chemical shifts of 9-H in **III** is δ 8.24–8.41 ppm, whereas the chemical shifts of 9-H in **IV** range from δ 6.10 to 6.51 ppm. These data allowed us to reliably distinguish isomers **III** and **IV**.

We also measured the ^1H NMR spectra of isomeric compounds **IIIb**, **IVb** and **IIIe**, **IVe** with addition of an optically active lanthanide shift reagent (LSR), tris[3-(heptafluoropropylhydroxymethylene)camphorato]europium(III) [$Eu(hfc)_3$]. Appreciable shifts of signals from the 3′-H, 5′-H, and $CH_3C_6H_4$ protons in the aryl substituent were observed only for compounds **IIIb** and **IIIe**. Shifts of signals from protons of the ethoxycarbonyl group and 6-H in the benzothiazole fragment were observed for both **IIIe** and **IVe** (Table 3).

Unlike the 6-H and (for compound **IIIe**) CH_2CH_3 signals which shift downfield, the signals of 3′-H, 5′-H, and $CH_3C_6H_4$ are displaced upfield. In addition,

Table 1. Yields, melting points, and elemental analyses of compounds **IIIa**–**IIIl** and **IVa**–**IVl**

Comp. no.	Yield, %	mp, °C (solvent)	Found, %			Formula	Calculated, %		
			C	H	N		C	H	N
IIIa	45	200–201 (EtOH)	58.27	2.51	11.06	$C_{18}H_{10}F_3N_3OS$	57.90	2.68	11.26
IIIb	48	201–202 (EtOH)	59.19	3.31	10.59	$C_{19}H_{12}F_3N_3OS$	58.91	3.10	10.85
IIIc	52	182–183 (EtOH)	56.20	3.17	10.05	$C_{19}H_{12}F_3N_3O_2S$	56.57	2.98	10.42
IIId	49	223–224 (EtOH)	57.27	3.69	6.88	$C_{20}H_{15}F_3N_2O_3S$	57.14	3.57	6.67
IIIe	51	210–212 (EtOH)	57.81	4.06	6.61	$C_{21}H_{17}F_3N_2O_3S$	58.06	3.92	6.45
IIIf	71	193–194 (EtOH)	56.40	3.84	6.10	$C_{21}H_{17}F_3N_2O_4S$	56.00	3.78	6.22
IIIg	55	219–220 (EtOH)	62.56	3.55	5.92	$C_{25}H_{17}F_3N_2O_3S$	62.24	3.53	5.81
IIIh	59	207–204 (EtOH)	62.81	3.97	5.41	$C_{26}H_{19}F_3N_2O_3S$	57.90	2.68	5.28
IIIi	39	223–224 (*i*-PrOH)	63.75	3.92	5.51	$C_{26}H_{19}F_3N_2O_4S$	61.18	3.73	5.39
IIIj	41	267–268 (dioxane–DMF, 6 : 1)	60.18	2.84	9.00	$C_{24}H_{14}F_3N_3OS_2$	59.87	2.91	8.73
IIIk	42	278–279 (dioxane–DMF, 6 : 1)	60.94	3.08	8.46	$C_{25}H_{16}F_3N_3OS_2$	60.60	3.23	10.85
IIIl	41	263–264 (dioxane–DMF, 6 : 1)	58.54	3.06	8.35	$C_{25}H_{16}F_3N_3O_2S_2$	58.71	3.13	8.22
IVa	30	238–239 (EtOH)	57.83	2.77	11.05	$C_{18}H_{10}F_3N_3OS$	57.90	2.68	11.26
IVb	36	245–246 (dioxane)	58.81	3.29	10.97	$C_{19}H_{12}F_3N_3OS$	58.91	3.10	10.85
IVc	30	144–145 (EtOH)	56.35	2.79	10.26	$C_{19}H_{12}F_3N_3O_2S$	56.57	2.98	10.42
IVd	56	226–228 (EtOH)	56.91	3.44	6.60	$C_{20}H_{15}F_3N_2O_3S$	57.14	3.57	6.67
IVe	62	220–222 (EtOH)	58.41	4.03	6.67	$C_{21}H_{17}F_3N_2O_3S$	58.06	3.92	6.45
IVf	58	218–220 (EtOH)	55.73	3.82	6.01	$C_{21}H_{17}F_3N_2O_4S$	56.00	3.78	6.22
IVg	47	193–194 (EtOH)	62.49	3.50	5.99	$C_{25}H_{17}F_3N_2O_3S$	62.24	3.53	5.81
IVh	47	206–207 (*i*-PrOH)	63.10	3.95	5.70	$C_{26}H_{19}F_3N_2O_3S$	63.16	3.85	5.67
IVi	53	211–214 (*i*-PrOH)	61.33	3.86	5.64	$C_{26}H_{19}F_3N_2O_4S$	61.18	3.73	5.39
IVj	60	280–281 (dioxane–DMF, 5 : 1)	59.63	2.83	8.88	$C_{24}H_{14}F_3N_3OS_2$	59.87	2.91	8.73
IVk	58	271–272 (dioxane–DMF, 5 : 1)	60.77	3.35	8.72	$C_{25}H_{16}F_3N_3OS_2$	60.60	3.23	8.48
IVl	37	265–266 (dioxane–DMF, 6 : 1)	58.96	3.27	7.94	$C_{25}H_{16}F_3N_3O_2S_2$	58.71	3.13	8.22

Table 2. IR and ^1H and ^{19}F NMR spectra of compounds **IIIa**–**IIIl** and **IVa**–**IVl**

Comp. no.	IR spectrum (KBr), ν, cm^{-1}			^1H NMR spectrum, δ, ppm (*J*, Hz)	^{19}F NMR spectrum, δ_F, ppm
	C=O	N–H	C≡N		
IIIa[a]	1720	3250	2220	7.29–7.41 m (2H, 7-H, 8-H), 7.51 m (3H, H_{arom}), 7.70 m (2H, H_{arom}), 7.78 d (1H, 6-H, *J* = 7.4), 8.27 d (1H, 9-H, *J* = 8.3), 9.71 s (1H, NH)	–75.76
IIIb	1720	3240	2220	2.37 s (3H, CH_3), 7.31–7.42 m (3H, H_{arom}, 7-H, 8-H), 7.53 d (2H, H_{arom}, *J* = 8.1), 7.74 d (1H, 6-H, *J* = 8.1), 8.24 d (1H, 9-H, *J* = 8.1), 9.66 s (1H, NH)	–75.97

Table 2. (Contd.)

Comp. no.	IR spectrum (KBr), ν, cm^{-1}			^1H NMR spectrum, δ, ppm (*J*, Hz)	^{19}F NMR spectrum, δ_F, ppm
	C=O	N–H	C≡N		
IIIc	1725	3220	2220	3.82 s (3H, OCH_3), 7.01 d (2H, H_{arom}, *J* = 9.2), 7.26–7.40 m (2H, 7-H, 8-H), 7.56 d (2H, H_{arom}, *J* = 9.2), 7.73 d (1H, 6-H, *J* = 7.9), 8.28 d (1H, 9-H, *J* = 7.9), 9.64 s (1H, NH)	–76.28
IIId	1725	3340	–	0.71 t (3H, CH_3, *J* = 6.9), 3.78 q (2H, OCH_2, *J* = 6.9), 7.28–7.56 m (7-H, 8-H, H_{arom}), 7.71 d (1H, 6-H, *J* = 7.2), 8.36 d (1H, 9-H, *J* = 8.1), 9.31 s (1H, NH)	–75,16
IIIe	1715	3250	–	0.79 t (3H, CH_3, *J* = 6.9), 2.41 s (3H, CH_3), 3.83 q (2H, OCH_2, *J* = 6.9), 7.25 d (2H, H_{arom}, *J* = 8.0), 7.28–7.39 m (2H, 7-H, 8-H), 7.45 d (2H, H_{arom}, *J* = 8.0), 7.75 d (1H, 6-H, *J* = 7.2), 8.41 d (1H, 9-H, *J* = 8.4), 9.27 s (1H, NH)	–75,12
IIIf	1715	3240	–	0.78 t (3H, CH_3, *J* = 6.9), 3.75–3.82 m (5H, OCH_2, OCH_3), 6.91 d (2H, H_{arom}, *J* = 8.7), 7.27–7.36 m (2H, 7-H, 8-H), 7.45 d (2H, H_{arom}, *J* = 8.7), 7.69 d (1H, 6-H, *J* = 7.8), 8.34 d (1H, 9-H, *J* = 7.8), 9.22 s (1H, NH)	–75,26
IIIg	1725	3250	–	4.79 d (1H, H_A, $OC\mathbf{H}_2C_6H_5$, *J* = 12), 4.83 (1H, H_B, $OC\mathbf{H}_2C_6H_5$, *J* = 12), 6.76 d (2H, H_{arom}, *J* = 8.7), 7.20–7.51 m (11H, 7-H, 8-H, H_{arom}), 7.72 d (1H, 6-H, *J* = 8.1), 8.34 d (1H, 9-H, *J* = 8.4), 9.30 s (1H, NH)	–75,01
IIIh	1720	3240	–	2.32 s (3H, CH_3), 4.74 d (1H, H_A, $OC\mathbf{H}_2C_6H_5$, *J* = 12.3), 4.91 d (1H, H_B, $OC\mathbf{H}_2C_6H_5$, *J* = 12,3), 6.74 d (2H, H_{arom}, *J* = 7.9), 7.05 d (2H, H_{arom}, *J* = 7.9), 7.21–7.42 m (9H, 7-H, 8-H, H_{arom}), 7.71 d (1H, 6-H, *J* = 7.5), 8.35 d (1H, 9-H, *J* = 7.8), 9.24 s (1H, NH)	–75.09
IIIi	1725	3230	–	3.76 s (3H, OCH_3), 4.78 d (1H, H_A, $OC\mathbf{H}_2C_6H_5$, *J* = 12.1), 4.90 d (1H, H_B, $OC\mathbf{H}_2C_6H_5$, *J* = 12.1), 6.72–6.83 m (4H, H_{arom}), 7.17–7.44 m (8H, H_{arom}), 7.66 d (1H, 6-H, *J* = 7.4), 8.34 d (1H, 9-H, *J* = 7.8), 9.17 s (1H, NH)	–75.35
IIIj	1715	3250	–	7.21–7.40 m (4H, 7-H, 8-H, H_{arom}), 7.52 m (3H, H_{arom}), 7.66–7.89 m (4H, H_{arom}), 7.92 d (1H, 6-H, *J* = 8.1), 8.38 d (1H, 9-H, *J* = 8.1), 9.48 s (1H, NH)	–74.24
IIIk	1720	3220	–	2.42 s (3H, CH_3), 7.21–7.40 m (6H, H_{arom}), 7.62–7.73 m (4H, H_{arom}), 7.90 d (1H, 6-H, *J* = 8.0), 8.37 d (1H, 9-H, *J* = 8.1), 9.39 s (1H, NH)	–74.60
IIIl	1725	3235	–	3.85 s (3H, OCH_3), 7.03 d (2H, H_{arom}, *J* = 8.9), 7.21–7.45 m (4H, H_{arom}), 7.64–7.74 m (4H, H_{arom}), 7.89 d (1H, 6-H, *J* = 8.2), 8.37 d (1H, 9-H, *J* = 8.2), 9.36 s (1H, NH)	–74.80
IVa[b]	1665	3080 3180 3310	2230	6.51 d (1H, 9-H, *J* = 8.4), 7.00 t (1H, 8-H, *J* = 8.4), 7.21 t (1H, 7-H, *J* = 8.4), 7.58 m (3H, H_{arom}), 7.75 d (2H, H_{arom}, *J* = 6.7), 7.89 d (1H, 6-H, *J* = 8.4), 9.31 s (1H, NH)	–74.38
IVb	1675	3100 3190 3300	2230	2.42 s (3H, CH_3), 6.10 d (1H, 9-H, *J* = 8.3), 7.02 t (1H, 8-H, *J* = 8.3), 7.18 t (1H, 7-H, *J* = 7.6), 7.35 d (2H, H_{arom}, *J* = 9.1), 7.59 d (2H, H_{arom}, *J* = 7.6), 7.86 d (1H, 6-H, *J* = 8.3), 9.22 s (1H, NH)	–74.51
IVc	1670	3110 3190 3290	2230	3.82 s (3H, OCH_3), 6.12 d (1H, 9-H, *J* = 8.7), 7.10 m (3H, 8-H, H_{arom}), 7.22 t (1H, 7-H, *J* = 7.9), 7.70 d (2H, H_{arom}, *J* = 8.7), 7.91 d (1H, 6-H, *J* = 7.9), 9.22 s (1H, NH)	–74.30

Table 2. (Contd.)

Comp. no.	IR spectrum (KBr), ν, cm^{-1}			^{1}H NMR spectrum, δ, ppm (*J*, Hz)	^{19}F NMR spectrum, δ_F, ppm
	C=O	N–H	C≡N		
IVd	1685	3065 3180 3310	– – –	1.33 t (3H, CH_3, *J* = 7.2), 4.26 q (2H, OCH_2, *J* = 7.2), 6.11 d (1H, 9-H, *J* = 8.4), 6.95 t (1H, 8-H, *J* = 8.2), 7.15 t (1H, 7-H, *J* = 7.3), 7.50–7,71 m (5H, H_{arom}), 7.79 d (1H, 6-H, *J* = 7.2), 8.81 s (1H, NH)	–73.97
IVe	1675	3055 3120 3310	– – –	1.32 t (3H, CH_3, *J* = 7.3), 2.41 s (3H, CH_3), 4.25 q (2H, OCH_2, *J* = 7.3), 6.15 d (1H, 9-H, *J* = 8.7), 6.97 t (1H, 8-H, *J* = 8.0), 7.16 t (1H, 7-H, J 8.2), 7.34 d (2H, H_{arom}, *J* = 8.1), 7.56 d (2H, H_{arom}, *J* = 8.1), 7.79 d (1H, 6-H, *J* = 7.2), 8.73 s (1H, NH)	–73.98
IVf	1680	3200 3310	–	1.32 t (3H, CH_3, *J* = 7.2), 3.85 s (3H, OCH_3), 4.24 q (2H, OCH_2, *J* = 7.2), 6.18 d (1H, 9-H, *J* = 8.4), 6.92–7.20 m (4H, 6-H, 7-H, 8-H, H_{arom}), 7.59 d (2H, H_{arom}, *J* = 7.8), 8.69 s (1H, NH)	–74.17
IVg	1680	3050 3180 3320	–	5.26 d (1H, H_A, $OC\mathbf{H}_2C_6H_5$, *J* = 12), 5.36 d (1H, H_B, $OC\mathbf{H}_2C_6H_5$, *J* = 12), 6.13 d (1H, 9-H, *J* = 8.1), 6.96 t (1H, 8-H, *J* = 8.4), 7.16 t (1H, 7-H, *J* = 8.1), 7.18–7.69 m (10H, H_{arom}), 7.80 d (1H, 6-H, *J* = 7.4), 8.84 s (1H, NH)	–73.93
IVh	1700	3160 3310		2.43 s (3H, CH_3), 5.26 d (1H, H_A, $OC\mathbf{H}_2C_6H_5$, *J* = 13.2), 5.37 d (1H, H_B, $OC\mathbf{H}_2C_6H_5$, *J* = 13.2), 6.18 d (1H, 9-H, *J* = 8.4), 6.99 t (1H, 8-H, *J* = 7.8), 7.17 t (1H, 7-H, *J* = 7.8), 7.18–7.57 m (9H, H_{arom}), 7.81 d (1H, 6-H, *J* = 7.2), 8.78 s (1H, NH)	–73.94
IVi	1700	3170 3300	–	3.85 s (2H, OCH_3), 5,24 d (1H, H_A, $OC\mathbf{H}_2C_6H_5$, *J* = 13.2), 5.35 d (1H, H_B, $OC\mathbf{H}_2C_6H_5$, *J* = 13.2), 6.19 d (1H, 9-H, *J* = 8.4), 7.03–7.55 m (11H, 7-H, 8-H, H_{arom}), 7.77 d (1H, 6-H, *J* = 7.6), 8.66 s (1H, NH)	–74.19
IVj	1680	3210 3320	–	6.14 d (1H, 9-H, *J* = 8.1), 7.05–7.50 m (4H, 7-H, 8-H, H_{arom}), 7.62 m (3H, H_{arom}), 7.86 d (2H, H_{arom}, *J* = 7.1), 7.92–8.10 m (3H, 6-H, H_{arom}), 9.46 s (1H, NH)	–73.96
IVk	1670	3200 3300		2.40 s (3H, CH_3), 6.19 d (1H, 9-H, *J* = 8.5), 7.06–7.58 m (6H, 7-H, 8-H, H_{arom}), 7.70 d (2H, H_{arom}, *J* = 8.7), 7.90–8.08 m (3H, 6-H, H_{arom})	–74.03
IVl	1665	3075 3180 3290		3.84 s (3H, OCH_3), 6.20 d (1H, 9-H, *J* = 8.5), 7.10–7.47 m (6H, 7-H, 8-H, H_{arom}), 7.76 d (2H, H_{arom}, *J* = 8.5), 7.89–8.06 m (3H, 6-H, H_{arom}), 9.35 s (1H, NH)	–74.25

[a] ^{13}C NMR spectrum, δ_C, ppm: 67.75 q (C^3, $^2J_{CF}$ = 29 Hz); 71.34 (C^4); 116.99 (C≡N); 124.93 q (CF_3, $^1J_{CF}$ = 289.6); 116.21, 122.51, 125.86, 125.34, 127.20, 127.35, 128.73, 129.35, 135.60, 137.65 (C_6H_5, C_6H_4); 146.94 (C=O); 157.05 (C^{4a}).

[b] ^{13}C NMR spectrum, δ_C, ppm: 71.74 (C^4); 79.17 q (C^1, $^2J_{CF}$ = 31); 114.78 (C≡N); 124.17 q (CF_3, $^1J_{CF}$ = 296.9); 116.01, 123.64, 123.95, 124.61, 126.75, 127.65, 129.36, 130.86, 132.52, 138.40 (C_6H_5, C_6H_4); 157.61 (C^{4a}); 166.51 (C=O).

the latter are split due to the presence of diastereoisomeric pairs of the adducts, for the substrates possess a chiral center. Anomalous shifts of the above proton signals (Δδ –0.58 to –1.67 ppm) may be interpreted in terms of a specific structure of the LSR–substrate adduct [14]. Assuming that the europium ion coordinates at the carbonyl oxygen atom of the cyclic urea fragment, the angle between the principal magnetic axis of the dipolar field induced by the europium ion (which passes along the Eu←O dative bond) and the Eu···3′-H (5′-H) (or Eu···C$\mathbf{H}_3C_6H_4$) line exceeds the magic angle for pseudocontact effect of paramagnetic ion, 54°44′ [15] (see figure). In this case, the induced shifts become less than zero, as is actually observed for compounds **IIIb** and **IIIe**.

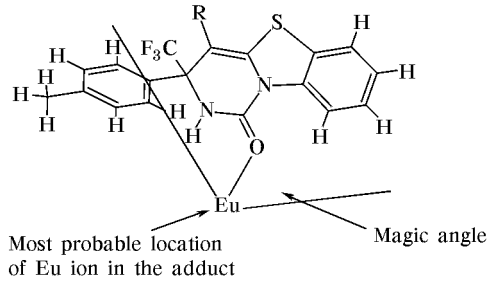
The assumed structures are also confirmed by comparison of the ^{13}C NMR spectra of compounds **IIIa** and **IVa** with those of structurally related 2,3-dihydro-

Table 3. Eu(hfc)$_3$-Induced shifts of proton signals in the ^{1}H NMR spectra of compounds **IIIb**, **IIIe**, and **IVe**

Comp. no.	Shift Δδ, ppm				
	6-H	3′-H, 5′-H	$CH_3C_6H_4$	CH_2CH_3	CH_2CH_3
IIIb	1.26	–0.83 –1.17	–0.58 –0.78	–	–
IIIe	1.57	–1.18 –1.67	–0.85 –1.11	0.73	0.34
IVe	1.22	–	–	1.45	0.53

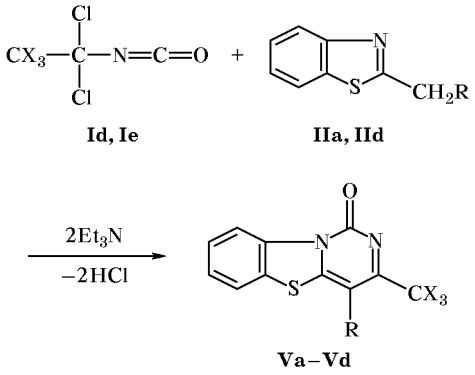
1*H*-pyrido[1,2-*c*]pyrimidin-1-ones and 2,3-dihydro-1*H*-pyrido[1,2-*c*]pyrimidin-3-ones containing analogous pyrimidine fragments [1]. In particular, the signal from the carbonyl carbon atom in compound **IIIa** appears as a singlet at δ_C 149.94 ppm, and that of C^3 is a quartet at δ_C 67.75 ppm ($^2J_{CF}$ = 29 Hz). In the spectrum of **IVa**, the C^1 signal is a quartet at δ_C 79.17 ppm ($^2J_{CF}$ = 31 Hz), while the carbonyl carbon signal is located at δ_C 166.51 ppm.

With a view to obtain nonhydrogenated analogs of pyrimido[6,1-*b*][1,3]benzothiazoles **III** and **IV** we examined the reactions of 1,1-dichloroalkyl isocyanates **Id** and **Ie** and methyl 1-chloroalkylidenecarbamates **If** and **Ig** with 2-benzothioazolylacetonitrile (**IIa**) and bis(2-benzothiazolyl)methane (**IId**). Like isocyanates **Ia**–**Ic**, their more electrophilic analogs **Id** and **Ie** smoothly reacted with difunctional nucleophiles **IIa** and **IId** in benzene in the presence of 2 equiv of triethylamine to afford 1*H*-pyrimido[6,1-*b*]-[1,3]benzothiazol-1-ones **Va**–**Vd** (Scheme 3). When the reaction was carried out in boiling benzene or toluene without addition of triethylamine, the process was not selective. According to the ^{1}H and ^{19}F NMR data, mixtures of products were formed, which were difficult to separate.



Structure of the Eu(hfc)$_3$ adducts with compounds **IIIb** and **IIIe**.

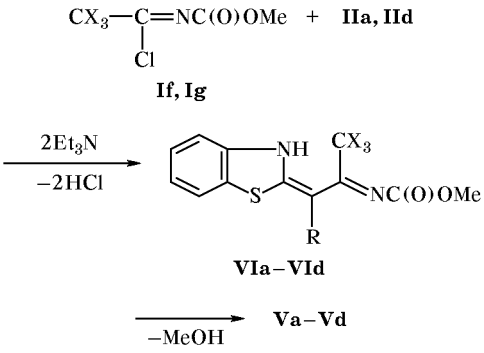
Scheme 3.



I, X = F (**d**), Cl (**e**); **II**, R = CN (**a**), 2-benzothiazolyl (**d**); **V**, R = CN, X = F (**a**), Cl (**b**); R = 2-benzothiazolyl, X = F (**c**), Cl (**d**).

Fused systems like **V** were also obtained as a result of regioselective cyclization of methyl 1-chloroalkylidenecarbamates **If** and **Ig** with substrates **IIa** and **IId** in the presence of triethylamine. Obviously, the first stage is C-iminoalkylation (Scheme 4). This follows from the isolation of a stable product which was assigned structure **VIc** on the basis of the ^{1}H and ^{19}F NMR spectra. Compound **VIc** was quantitatively converted into **Vc** by heating in boiling *o*-xylene. On the other hand, methyl 1,2,2,2-tetrachloroethylidenecarbamate (**Ig**) reacted with bis(2-benzothiazolyl)-methane (**IId**) only on heating in toluene, i.e., under conditions corresponding to cyclization of **VId** to **Vd**. It should be noted that the condensation of carbamates **If** and **Ig** with more reactive 2-benzothiazolylacetonitrile (**IIa**) begins even at room temperature and is completed by heating in boiling toluene, leading to products **Va** and **Vb**. In the IR spectra of **Va**–**Vd**, the carbonyl absorption band is displaced to the region 1705–1710 cm^{-1} due to conjugation with the endo-

Scheme 4.



I, X = F (**f**), Cl (**g**); **V**, **VI**, R = CN, X = F (**a**), Cl (**b**); R = 2-benzothiazolyl, X = F (**c**), Cl (**d**).

cyclic C=N bond. The 9-H proton in these compounds is deshielded to a stronger extent than in **III**, and its signal appears in the ^{1}H NMR spectra as a doublet at δ 9.00–9.13 ppm.

EXPERIMENTAL

The IR spectra of samples pelleted with KBr were recorded on a UR-20 instrument. The ^{1}H and ^{19}F NMR spectra of solutions in $(CD_3)_2SO$–CCl_4 (2 : 1) and $CDCl_3$ (with addition of LSR) were obtained on a Varian Gemini spectrometer operating at 300 (^{1}H) and 188.28 MHz (^{19}F); tetramethylsilane and CCl_3F were used as internal references for ^{1}H and ^{19}F, respectively. The ^{13}C NMR spectra were measured on a Varian Gemini instrument at 75 MHz from solutions in $(CD_3)_2SO$ using TMS as internal reference.

1-Chloroalkyl isocyanates **Ia**–**Ic** were prepared by the procedure described in [16], 1,1-dichloroalkyl isocyanates **Id** and **Ie** were obtained as described in [17, 18], and methyl 1-chloroalkylidenecarbamates **If** and **Ig** were synthesized according to the procedure reported in [19].

3-Aryl-4-R-3-trifluoromethyl-2,3-dihydro-1*H*-pyrimido[6,1-*b*][1,3]benzothiazol-1-ones IIIa–IIIl. A solution of 0.003 mol of 1-chloroalkyl isocyanate **Ia**–**Ic** in 3 ml of benzene was added to a solution or suspension of 0.003 mol of 2-substituted benzothiazole **IIa**–**IId** in 5 ml of benzene; after 0.5 h, a solution of 0.313 g (0.0031 mol) of triethylamine in 3 ml of benzene was added with stirring. The mixture was stirred for 1 h, left to stand for 24 h, and filtered. The solid precipitate was dried and washed with water (2 × 20 ml). The filtrate was evaporated, 2–3 ml of ethanol was added to the oily residue, and the mixture was heated to the boiling point. After cooling, the precipitate was filtered off, combined with the first portion, and recrystallized.

3-Aryl-4-R-3-trifluoromethyl-2,3-dihydro-1*H*-pyrimido[6,1-*b*][1,3]benzothiazol-3-ones IVa–IVl. A mixture of 0.003 mol of 1-chloroalkyl isocyanate **Ia**–**Ic** and an equimolar amount of 2-substituted benzothiazole **IIa**–**IId** in 20 ml of toluene was heated for 10–12 h under reflux. The mixture was cooled, the precipitate was filtered off, the filtrate was evaporated, 5 ml of ethanol was added, and the mixture was heated to the boiling point and cooled. The precipitate was filtered off, combined with the first portion of the product, and recrystallized.

4-R-3-Trihalomethyl-1*H*-pyrimido[6,1-*b*][1,3]benzothiazol-1-ones Va–Vd. *a*. A solution of 0.003 mol of 1,1-dichloroalkyl isocyanate **Id** or **Ie** in 5 ml of toluene was added dropwise with stirring to a solution or suspension of 0.003 mol of 2-substituted benzothiazole **IIa**–**IId** in 5 ml of toluene, and a solution of 0.62 g (0.061 mol) of triethylamine in 4 ml of toluene was then added dropwise with stirring and cooling. The mixture was stirred at room temperature and was left to stand for 24 h. The precipitate was filtered off, washed with water, and recrystallized from appropriate solvent.

b. A solution of 0.003 mol of methyl 1-chloroalkylidenecarbamate **If** or **Ig** in 5 ml of toluene was added dropwise with stirring to a solution or suspension of 0.003 mol of 2-substituted benzothiazole **IIa**–**IId** in 5 ml of toluene, and a solution of 0.313 g (0.0031 mol) of triethylamine in 2 ml of toluene was then added. In the reactions of **IIa** with **If** and **Ig**, the mixture was stirred for 2 h at room temperature, the precipitate of triethylamine hydrochloride was filtered off, the filtrate was heated for 2–3 h under reflux, the solvent was evaporated, 5 ml of ethanol was added to the residue, the mixture was heated to the boiling point and cooled, and the precipitate was filtered off and recrystallized. In the reaction of **IId** with **Ig**, the mixture was heated for 10 h under reflux and cooled, and the precipitate was filtered off, washed with water, and recrystallized. In the reaction of **IId** with **If**, the mixture was left to stand for 48 h at room temperature, the precipitate was filtered off, washed with water, and dried, the filtrate was evaporated, 5 ml of ethanol was added to the residue, the mixture was heated to the boiling point and cooled, and the precipitate was filtered off, combined with the first portion of the product, and recrystallized. Compound **IVc** thus obtained was heated for 12 h in boiling *o*-xylene. After cooling, the precipitate was filtered off and recrystallized.

1-Oxo-3-trifluoromethyl-1*H*-pyrimido[6,1-*b*]-[1,3]benzothiazole-4-carbonitrile (Va). Yield 60% (*a*), 57% (*b*). mp 260–261°C (from ethanol). IR spectrum, ν, cm^{-1}: 1710 (C=O), 2240 (C≡). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 7.74–7.80 m (2H, 7-H, 8-H), 8.36 d (1H, 6-H, *J* = 8.1), 9.06 d (1H, 9-H, *J* = 8.1). ^{19}F NMR spectrum: δ_F –68.54 ppm. Found, %: C 49.17; H 1.09; N 14.10. $C_{12}H_4F_3N_3OS$. Calculated, %: C 48.81; H 1.36; N 14.24.

1-Oxo-3-trichloromethyl-1*H*-pyrimido[6,1-*b*]-[1,3]benzothiazole-4-carbonitrile (Vb). Yield 39% (*a*), 19% (*b*). mp 249–250°C (from dioxane–DMF, 3 : 1). IR spectrum, ν, cm^{-1}: 1705 (C=O), 2235 (C≡N). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 7.70–7.82 m (2H, 7-H, 8-H), 8.30 d (1H, 6-H, *J* = 7.3), 9.00 d (1H, 9-H, *J* = 7.7). Found, %: C 41.51; H 0.97;

N 12.45. $C_{12}H_4Cl_3N_3OS$. Calculated, %: C 41.80; H 1.16; N 12.19.

4-(2-Benzothiazolyl)-3-trifluoromethyl-1*H*-pyrimido[6,1-*b*][1,3]benzothiazol-1-one (Vc). Yield 61% (*a*), 58% (*b*). mp 261–262°C (from DMF). IR spectrum, ν, cm^{-1}: 1715 (C=O). ^1H NMR spectrum, δ, ppm (*J*, Hz): 7.58–7.75 m (4H, H_{arom}), 8.18–8.30 m (3H, H_{arom}), 9.13 d (1H, 9-H, *J* = 8.1). ^{19}F NMR spectrum: δ_F –63.42 ppm. Found, %: C 53.32; H 2.18; N 10.20. $C_{18}H_8F_3N_3OS_2$. Calculated, %: C 53.32; H 1.98; N 10.42.

4-(2-Benzothiazolyl)-3-trichloromethyl-1*H*-pyrimido[6,1-*b*][1,3]benzothiazol-1-one (Vd). Yield 49% (*a*), 38% (*b*). mp 263–264°C (from dioxane). IR spectrum, ν, cm^{-1}: 1710 (C=O). ^1H NMR spectrum, δ, ppm (*J*, Hz): 7.52–7.75 m (4H, H_{arom}), 8.06–8.23 m (3H, H_{arom}), 9.11 d (1H, 9-H, *J* = 8.3). Found, %: C 48.05; H 1.50; N 9.07. $C_{18}H_8Cl_3N_3OS_2$. Calculated, %: C 47.73; H 1.77; N 9.28.

Methyl 2,2-bis(2-benzothiazolyl)-1-trifluoromethylvinylcarbamate (VIc). Yield 58%. mp 259–260°C (from dioxane). IR spectrum, ν, cm^{-1}: 1737 (C=O). ^1H NMR spectrum, δ, ppm: 3.68 s (3H, CH_3), 7.52–7.62 m (4H, H_{arom}), 7.93–8.20 m (4H, H_{arom}), 10.21 s (1H, NH). ^{19}F NMR spectrum: δ_F –62.02 ppm. Found, %: C 52.14; H 2.89; N 9.39. $C_{19}H_{12}F_3N_3O_2S$. Calculated, %: C 52.47; H 2.76; N 9.65.

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