ISSN 1070-4280, Russian Journal of Organic Chemistry, 2019, Vol. 55, No. 2, pp. 215–226. © Pleiades Publishing, Ltd., 2019.
Russian Text © I.V. Dyachenko, V.D. Dyachenko, P.V. Dorovatovskii, V.N. Khrustalev, V.G. Nenaidenko, 2019, published in Zhurnal Organicheskoi Khimii, 2019, Vol. 55, No. 2, pp. 266–278.

Multicomponent Synthesis of Thiazole, Selenazole, Pyrane, and Pyridine Derivatives, Initiated by the Knoevenagel Reaction

I. V. Dyachenko[a], V. D. Dyachenko[a], P. V. Dorovatovskii[b], V. N. Khrustalev[b,c], and V. G. Nenaidenko[d,*]

[a] *Taras Shevchenko Lugansk National University, Oboronnaya ul. 2, Lugansk, 91011 Ukraine*

[b] *Kurchatov Institute National Research Center, ul. Akad. Kurchatova 1, Moscow, 123182 Russia*

[c] *Russian Peoples Friendship University, ul. Miklukho-Maklaya 6, Moscow, 117198 Russia*

[d] *Lomonosov Moscow State University, Leninskie Gory 1, Stroenie 3, Moscow, 119991, Russia*
**e-mail: nenajdenko@gmail.com*

Received June 1, 2018; revised June 16, 2018; accepted August 14, 2018

Abstract—(2*E*,2'*E*)-3,3'-(Propane-1,3-diyl)bis[oxy(4,1-phenylene)]bis[2-(4-aryl-1,3-thiazol-2-yl)acrylonitriles] and functionally substituted pyridines and fused pyrans containing a 3-[1,3-thi(selen)azol-2-yl]-substituent were synthesized by multicomponent condensations initiated by the Knoevenagel reaction. The structures of 2-amino-5-oxo-4-(1-phenylethyl)-4,5-dihydropyrano[3,2-*c*]chromene-3-carbonitrile and 2-amino-7-hexyloxy-4-cyclohexyl-4*H*-chromene-3-carbonitrile were studied by X-ray diffraction analysis.

Keywords: thiazole, selenazole, pyran, pyridine, Knoevenagel reaction, X-ray structural analysis

DOI: 10.1134/S1070428019020131

Thiazole, pyran and pyridine derivatives are widespread in nature, which explains the continuing interest of researchers to these heterocycles. Among synthetic substituted thiazole, compounds with antitumor [1, 2], antiviral [3], and bactericidal [4] properties were found. Some pyran derivatives are effective drugs for treating cancer (caspase activators and apoptosis inductors) [5] and neurogenerative diseases [6].

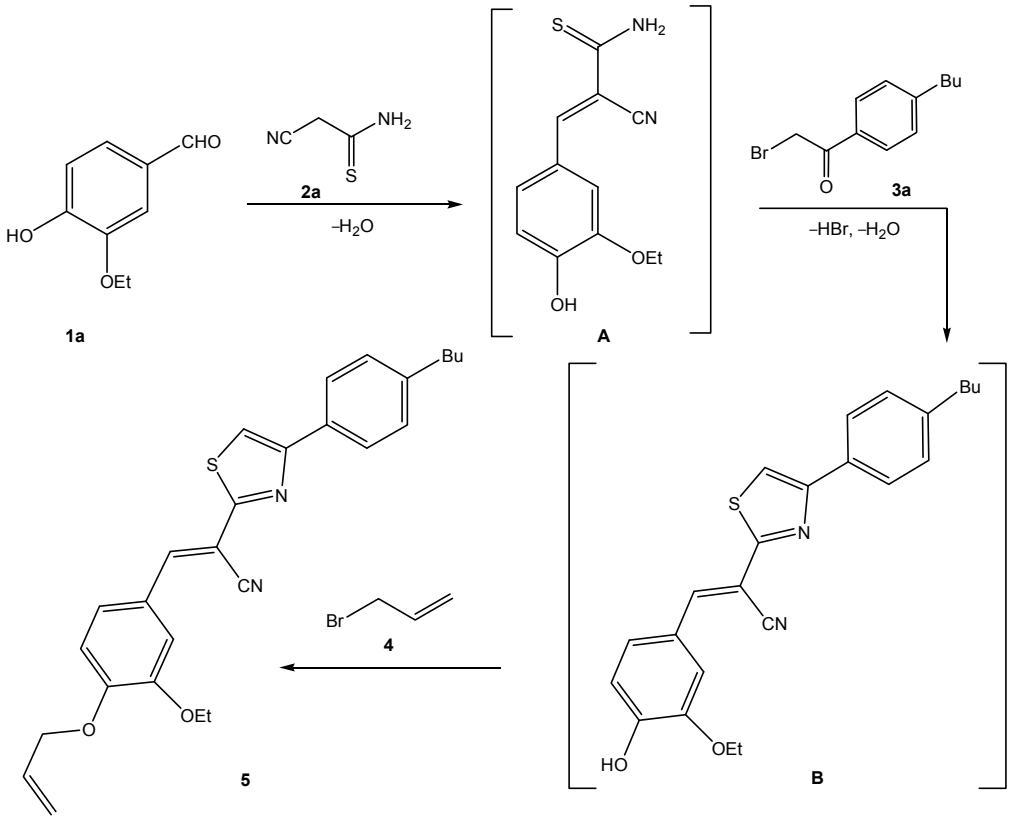
Functionalized pyridines can be used to treat seborrheic dermatitis [7], Alzheimer's disease [8], and CNS diseases [9]. Proceeding with the research into multicomponent condensations leading to potentially biologically active thiazole, pyran, and pyridine derivative [10–12], in the present work we studied the multicomponent syntheses of previously unknown compounds of the above classes of heterocycles, initiated by the Knoevenagel reaction.

It was shown that the condensation of 4-hydroxy-3-ethoxy benzaldehyde **1a** with cyanothiacetamide **2a**, 4-butylphenacyl bromide **3a**, and allyl bromide **4** forms (*E*)-3-[4-(allyloxy)-3-ethoxyphenyl)]-2-[4-(4-butylphenyl)thiazol-2-yl]acrylonitrile **5**. The condensation successfully occurs in DMF at 20°C in the presence of 10% aqueous NaOH and involves intermediate formation of Knoevenagel alkene **A** which then converts into Hantzsch thiazole **B**. The latter is readily alkylated with allyl bromide **4** under Williamson ether synthesis conditions to form ether **5** (Scheme 1).

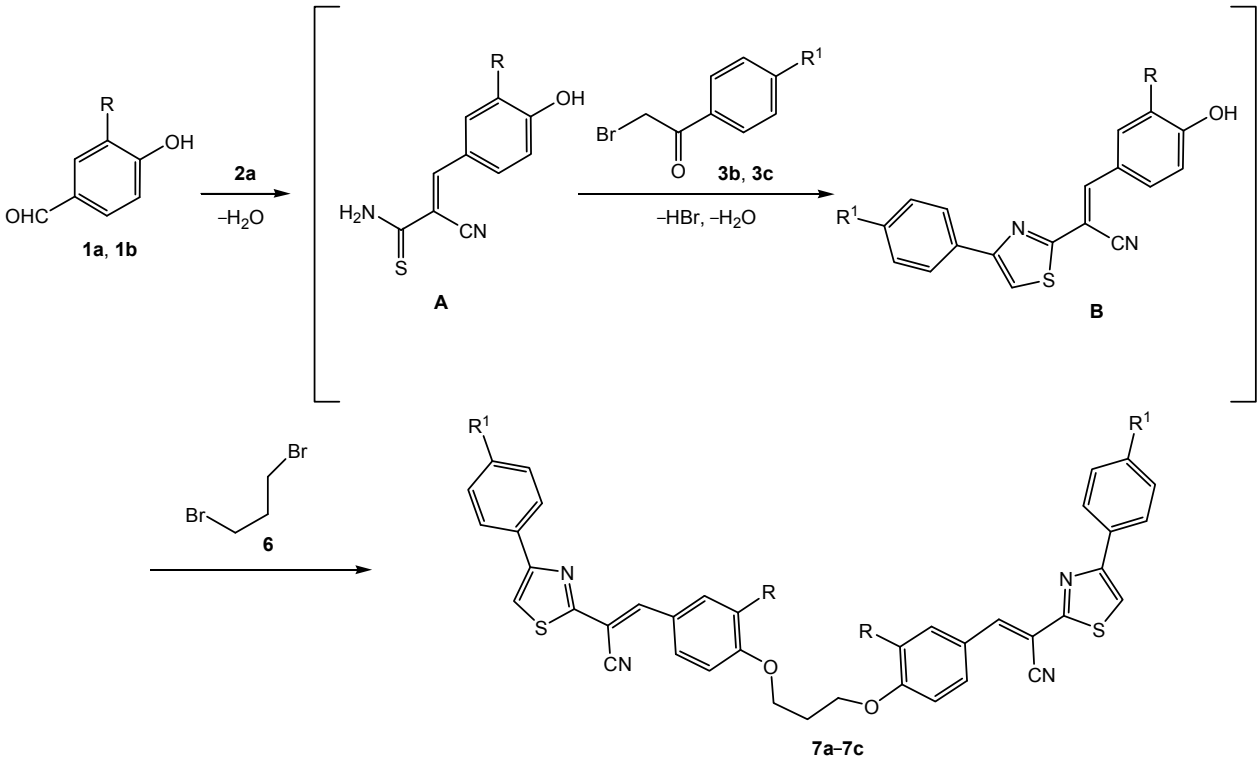
The use in this multicomponent condensation of aromatic aldehydes **1a** and **1b**, phenacyl bromides **3b** and **3c**, and 1,3-dibromopropane **6** allows, other conditions being equal, synthesis of (2*E*,2'*E*)-3,3'-(propane-1,3-diyl)bis[(oxy(4,1-phenylene)]bis[2-(4-aryl-1,3-thiazol-2-yl)acrylonitriles] **7a–7c**. Thus, all reaction steps can be performed in one pot, thereby substantially increasing molecular complexity (Scheme 2).

The reaction of 2-phenylpropanal **1c** with cyanothioacetamide **2a** and 4-hydroxycoumarin **8** in DMF in the presence of *N*-methylmorpholine at 20°C unexpectedly gave chromene **9**. The formation of this product is likely to include the following steps: 1) Michael addition of CH acid **8** to Knoevenagel alkene **A**; 2) intramolecular cyclization of intermediate **C** to fused pyran **9** with H_2S elimination.

Scheme 1.



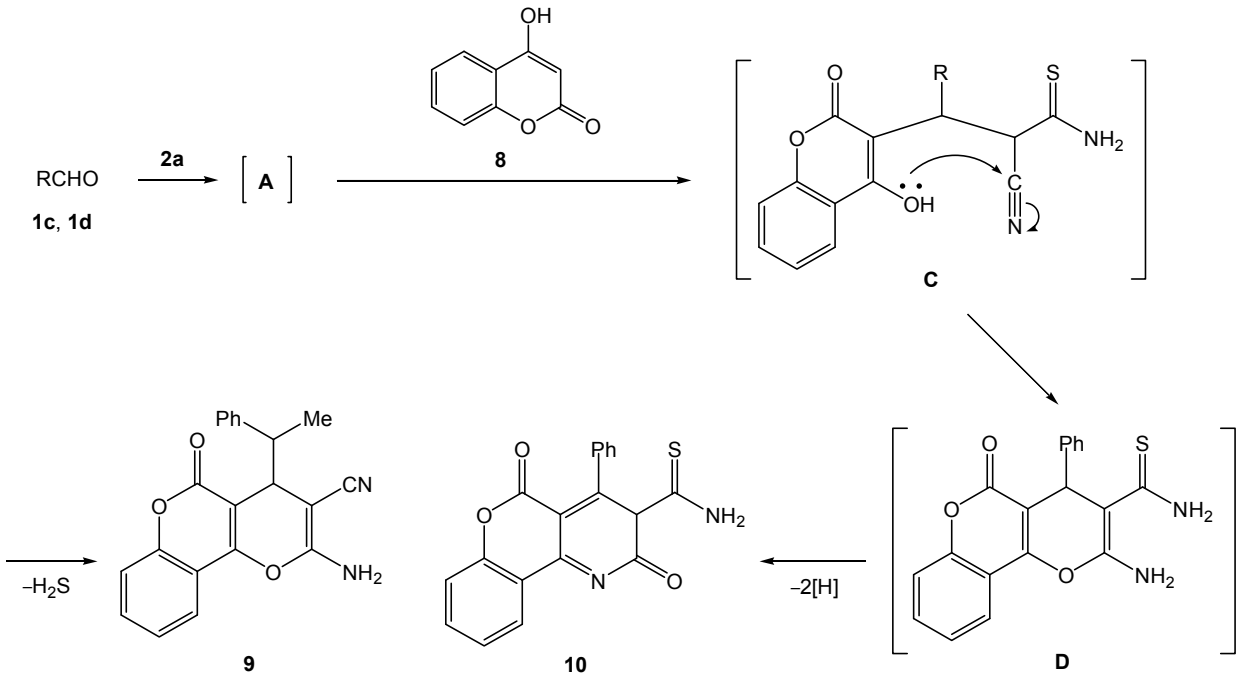
Scheme 2.



7a–7c

1, R = OEt (**a**), H (**b**); **3**, R^1 = 4-MeC_6H_4 (**b**), 4-$MeOC_6H_4$ (**c**); **7**, R = OEt, R^1 = 4-MeC_6H_4 (**a**); R = H, R^1 = 4-MeC_6H_4 (**b**); R = H, R^1 = 4-$MeOC_6H_4$ (**c**).

Scheme 3.



1, R = MeCHPh (**c**), Ph (**d**)

The same condensation with benzaldehyde **1d** formed 2,5-dioxo-4-phenyl-3,5-dihydro-2*H*-chromeno-[4,3-*b*]pyridine-3-carbothioamide **10**. Obviously, under the reaction conditions pyran **D** has underwent Dimroth recyclization [13] (Scheme 3).

The reaction of 4-ethoxybenzaldehyde **1e** with a double excess of cyanothioacetamide **2a**, equimolar amount of 3-(2-bromoacetyl)-7-hydroxy-2*H*-chromen-2-one **11**, and allyl bromide **4** in DMF in the presence of 10% aqueous NaOH yields 2-[2-(7-allyloxy-2-oxo-2*H*-chromen-3-yl)-2-oxoethylsulfanyl]-6-amino-4-(4-ethoxyphenyl)pyridin-3,5-dicarbonitrile **12**, a potential synthon for the synthesis of ring ensembles [14–16]. The reaction scheme includes formation of the corresponding Knoevenagel alkene **A** and Michael addition of cyanothioaceamide **2a** to the latter. Thus formed adduct **E** chemoselectively cyclizes into substituted pyridine-2-thiolate **F**, whose alkylation with α-bromoketone **11** gives ether **G**. The subsequent reaction of ether **G** with allyl bromine **4** in an alkaline medium yields Williamson ether **12** (Scheme 4).

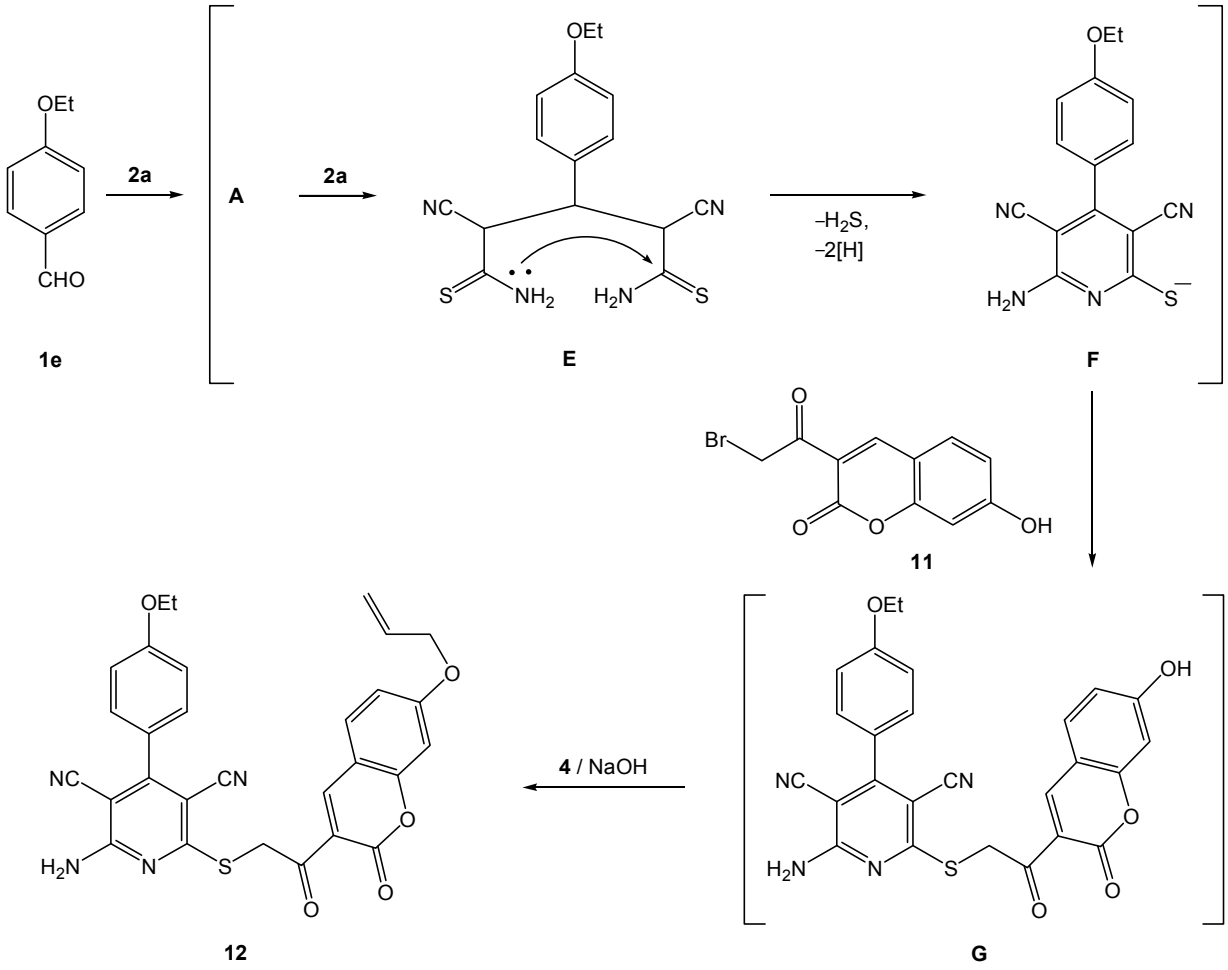
The structures of all the products were confirmed by spectral methods (see Experimental). The ^{1}H NMR spectra of substituted acrylonitrile **5** contain characteristic signals of the allyl substituent [17, 18] and the spectra of ethers **7a**–**7c**, propyl proton signals in the corresponding regions δ. The geometric isomerism was determined with account for the data in [19]. Unambiguous structural assessment of the multicomponent condensation product substituted pyrano[3,2-*c*]chromene **9** was performed by X-ray diffraction (XRD) analysis.

Compound **9** includes a system of fused pyran, pyranone, and benzene rings (Fig. 1). The benzopyranone fragment is nearly planar (the deviation of its atom from the mean plane is no larger than ±0.011°), whereas the pyran ring has a flattened boat conformation with the bend angle along the $O^1\cdots C^4$ line of 9.15(11)°. The N^2 atom has a trigonal pyramidal configuration [the sum of bond angles is 354(3)°].

Molecule **9** contains two asymmetric centers at C^4 and C^{12}. The crystal of compound **9** is a racemate and comprises enantiomeric pairs having a *rac*-(4*RS*,12*RS*) relative configuration of the centers. Molecules **9** form N–H···N and N-H···O hydrogen-bonded layers parallel to the $(10\bar{2})$ plane (Table 1, Fig. 2).

We also studied the multicomponent condensation of aromatic aldehydes **1e**–**1h**, cyanothio(seleno)-acetamides **2a** and **2b**, α-bromoketones **3d**–**3f**, and dimedone **13**. This process was performed in DMF at 20°C in the presence of morpholine. This cascade transformation results in the formation of 2-amino-4-

Scheme 4.



aryl(hetaryl)-7,7-dimethyl-3-[4-aryl(2-oxo-2*H*-chromen-3-yl)-1,3-thi(selen)azol-2-yl]-7,8-dihydro-4*H*-chromen-5(6*H*)-ones **14a–14d**. The reaction involves formation of Knoevenagel alkenes **A** as intermediates. After that a Hantzsch reaction occurs to form vinylthi-(selen)azoles **B**. Furhter on the latter take up dimedone **13** to give adducts **H** which undergo intramolecular cyclization into final heterocyclic systems **14a–14d** (Scheme 5). Their ^{1}H NMR spectra display characteristic proton signals of the dimedone fragments with a typical splitting and a C^{4}H-proton signals of the pyran fragment as a singlet at δ 4.46–4.83 ppm [20–23].

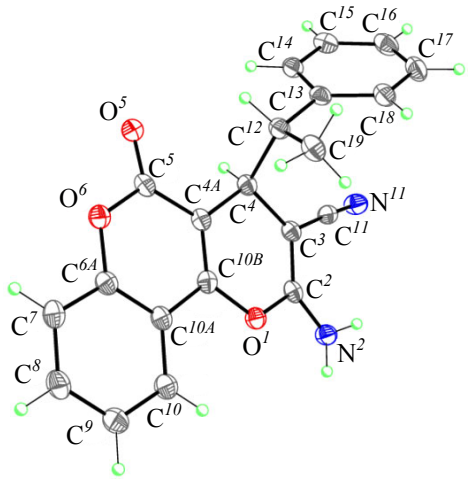


Fig. 1. Molecular structure of compound **9** (anisotropic displacement ellipsoids are drawn at the 50% probability level).

The condensation of cyclohexanecarbaldehyde **1i**, cyanothioacetamide **2a**, resorcinol **15**, and hexyl iodide **16** under the above conditions yields 2-amino-7-hexyloxy-4-cyclohexyl-4*H*-chromene-3-carbonitrile **17**, a promising half-product in the design of antimicrobial drugs *Staphylococcus aureas* [23]. The probable cheme condensation scheme involves the following steps. The first forms a Knoevenagel product, cyclohexylidenecyanothioaceamide **A**. The

Table 1. Hydrogen bonds in structures **9** and **17**.

D-H···A	*d*(D-H), Å	*d*(H···A), Å	*d*(D···A), Å	Angle (DHA), deg
Compound **9**				
N^{2}-H^{2}A···N^{11a}	0.899(15)	2.155(15)	3.0346(17)	165.7(13)
N^{2}-H^{2}B···O^{5b}	0.891(16)	2.046(16)	2.9219(15)	167.5(13)
Compound **17**				
N^{2}-H^{2}A···N^{9c}	0.915(18)	2.247(18)	3.1275(19)	161.3(15)
N^{2}-H^{2}B···N^{9d}	0.92(2)	2.38(2)	3.195(2)	148.1(17)
C^{6}-H^{6}···O^{7a}	0.95	2.47	3.413(2)	170.0

Symmetry codes:
[a] $-x, -y+1, -z+1$;
[b] $-x+1, y-1/2, -z+3/2$;
[c] $-x, -y, -z$;
[d] $x+1, y, z$.

subsequent Michael addition of resorcinol **15** to alkene **A** to form adduct **I** which undergoes chemoselective intramolecular heterocyclization into substituted pyran **K**, and the latter reacts by Williamson with hexyl iodide **16**, yielding ether **17** (Scheme 5).

For unambiguous structural assessment of the product of the considered multicomponent condensation, we performed an XRD analysis of the molecular and crystal structure of compound **17** (Figs. 3 and 4). The pyran ring of the benzopyran fragment in compound **17** has a flattened boat conformation with the bend angle along the $O^{1}\cdots C^{4}$ line of 11.98(12)°. The N^{2} angle has a trigonal bipyramidal configuration [the sum of bond angles is 352(4)°]. The hexyloxy substituent is in a completely transoid ("linear") conformation.

Molecule **17** has one asymmetric center at C^{4}. The crystal of compound **17** is a racemate. Molecules **17** form N–H···N and C–H···O hydrogen-bonded layers parallel to the $(01\bar{1})$ plane (Table 1, Fig. 4).

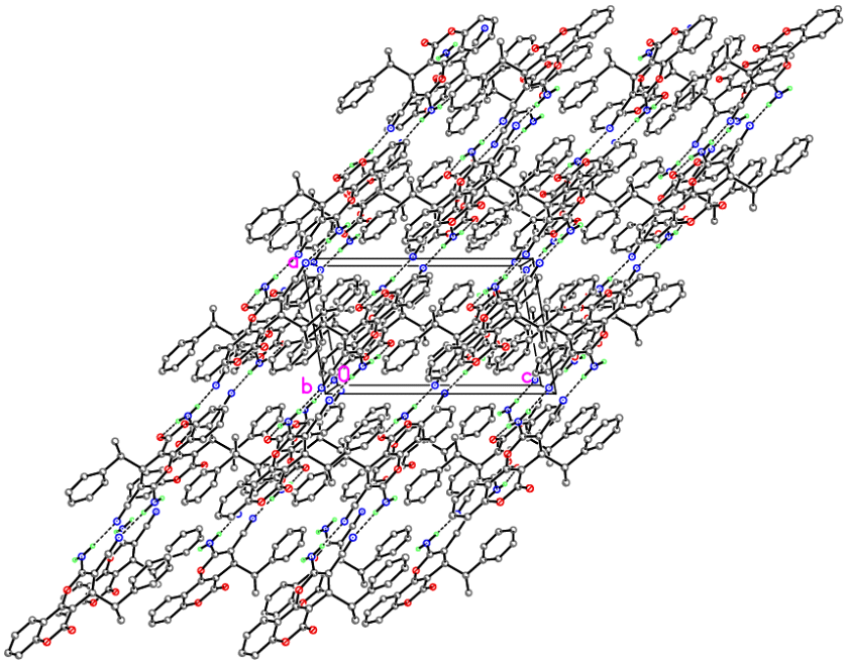
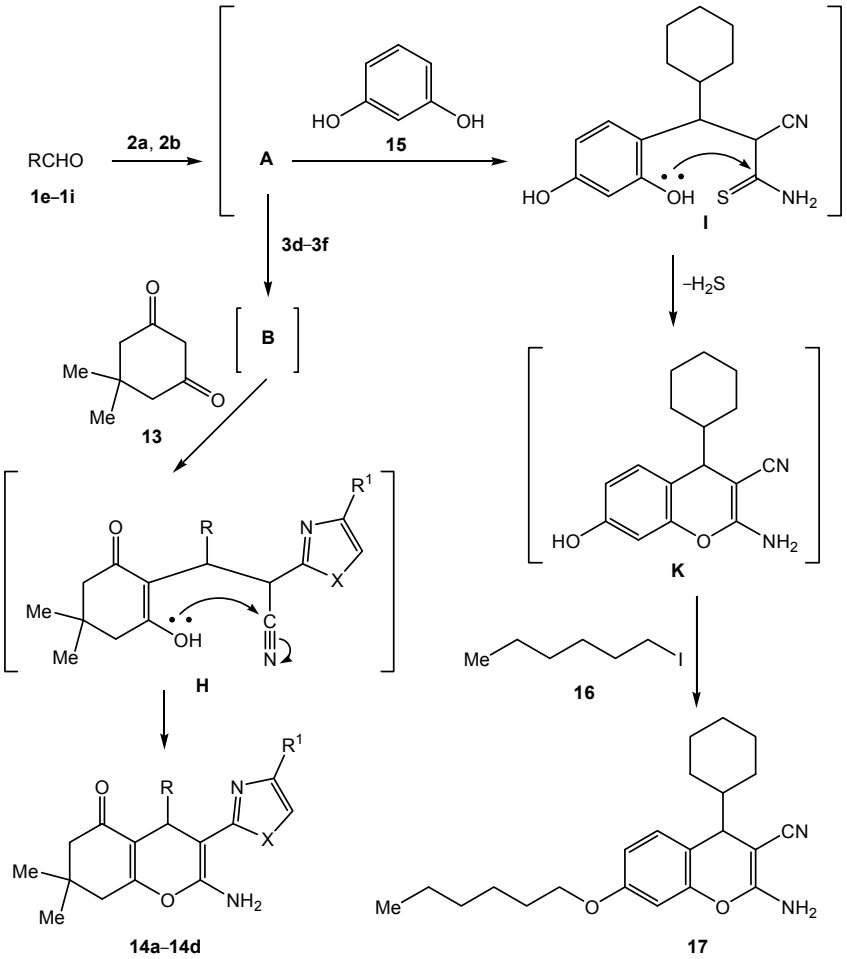


Fig. 2. Crystal structure of compound **9**.

Scheme 5.



1, R = thiophen-2-yl (**f**), 4-BrC_6H_4 (**g**), 2-furyl (**h**), cyclohexyl (**i**); **2**, X = Se (**b**); **3**, R^1 = coumarin-3-yl (**d**), Ph (**e**); 4-PhC_6H_4 (**f**); **14**, R = 4-$EtOC_6H_4$, R^1 = coumarin-3-yl, X = S (**a**); R = 4-BrC_6H_4, R^1 = Ph, X = Se (**b**); R = 2-furyl, R^1 = 4-PhC_6H_4, X = Se (**c**); R = thiophen-2-yl, R^1 = 4-PhC_6H_4, X = Se (**d**).

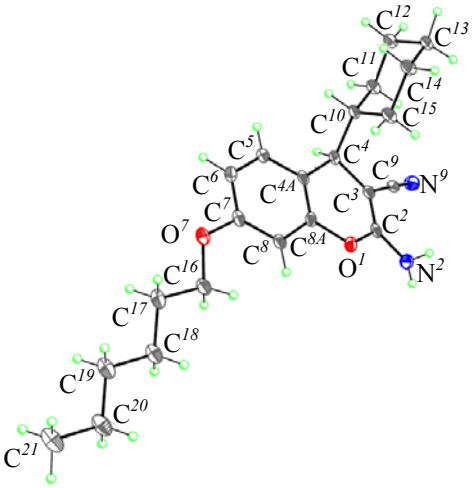


Fig. 3. Molecular structure of compound **17** (anisotropic displacement ellipsoids are drawn at the 50% probability level).

Thus, we have demonstrated the possibility of the multicomponent synthesis of heterocycles by reactions initiated by the Knoevenagel condensation.

EXPERIMENTAL

The unit cell parameters and reflection intensities for compounds **9** and **17** were measured on a Rayonix SX165 CCD two-coordinate detector (T 100 K, λ 0.96990 Å, φ scanning with a 1.0 deg increment) at the Belok synchrotron station, Kurchatov Institute National Research Center. Experimental data were processed using the iMosflm program from the CCP4 program suite [24]. The principal crystallographic data and refinement parameters are listed in Table 2. Absorption was included using the Scala program [25].

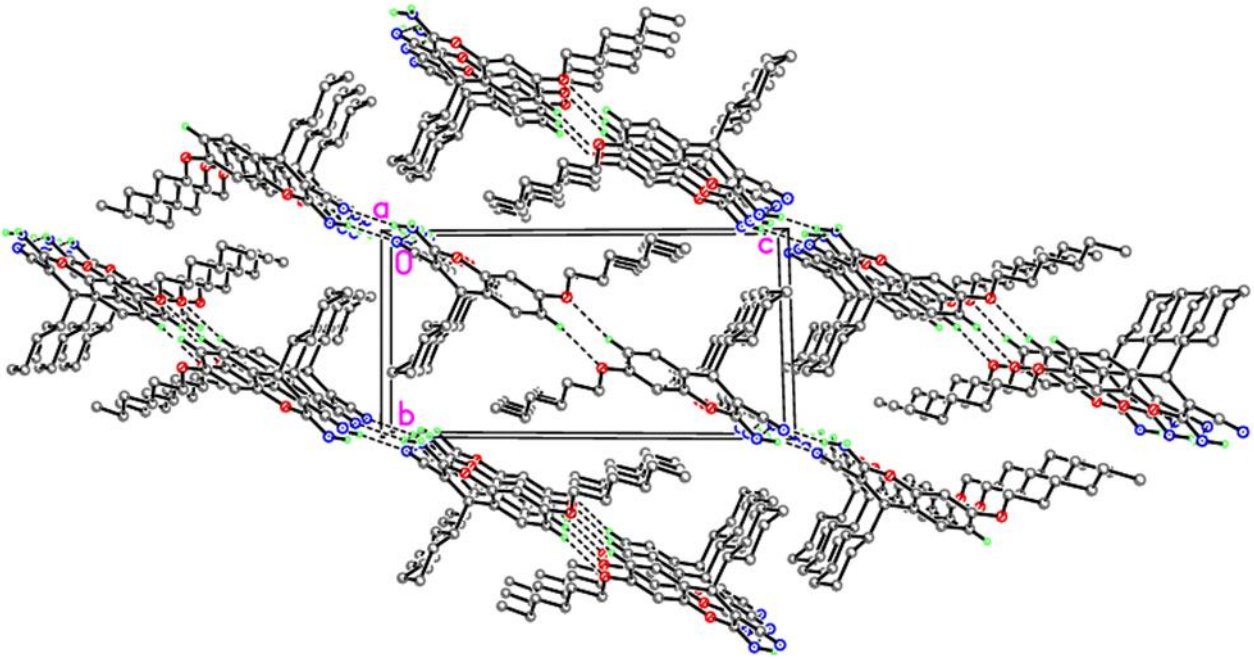


Fig. 4. Crystal structure of compound **17**.

The structures were solved by direct methods and refined by full-matrix least squares on F^2 with anisotropic displacement parameters for non-hydrogen atoms. The hydrogen atoms of amino groups were revealed by difference Fourier synthesis and refined isotropically with fixed displacement parameters [U_{iso}(H) = 1.2U_{eq}(N)[. The other hydrogen atoms were placed in geometrically calculated positions and refined riding on their carrier atoms with isotropic displacement parameters [U_{iso}(H) = 1.5U_{eq}(C) for CH_3 groups and U_{iso}(H) = 1.2U_{eq}(C) for the other groups]. All calculations were performed using the SHELXTL program suite [26]. The tabulated atomic coordinates, bond lengths, bond and torsion angles, and anisotropic displacement parameters for compounds **9** and **17** are deposited at the Cambridge Crystallographic Data Center [CCDC 1862036 (**9**) and CCDC 1862037 (**17**)].

The IR spectra were obtained on an IKS-40 instrument in mineral oil. The ^{1}H and ^{13}C NMR spectra were measured on a Varian VXR–400 spectrometer (399.97 and 100 MHz, respectively) in DMSO-d_6 solutions, internal standard TMS. The mass spectra of compounds **6**, **7c**, **9**, and **17** were obtained on a Thermo Scientific Orbitrap Elite hybrid mass spectrometer. The samples for high-resolution mass spectrometry were dissolved in 1 mL of DMSO, diluted 100 times with 1% HCOOH in CH_3CN, and infused to an ESI source at 40 μL/min. The spray needle voltage was 3.5 kV, and the capillary temperature was 275°C. The mass spectra were registered in the positive (PI) and negative ion modes with a resolution of 480000. The 2DMSO+H^+ cation (*m/z* 157.03515) and dodecyl sulfate anion (*m/z* 265.14789) were used as internal calibrants for the positive and negative ion modes, respectively. The mass spectra of the other compounds were measured on an Agilent LS/MSDLS system (matrix CH_3COOH, electron ionization at 70 eV). Elemental analysis was performed on a Perkin Elmer CHN analyzer. The melting points were measured on a Kofler hot stage. The reaction progress and purity of the synthesized compounds were monitored by TLC on Silufol UV-254 in an acetone–hexane (3 : 5) solvent system with development in iodine vapor and UV light.

(*E*)-3-(4-Allyloxy-3-ethoxyphenyl)-2-[4-(4-butylphenyl)-1,3-thiazol-2-yl]acrylonitrile (5). Morpholine, 3 drops, was added to a stirred solution of 1.7 g (10 mmol) 4-hydroxy-3-ethoxybenzaldehyde **1a** and 1.0 g (10 mmol) cyanothioaceamide **2a** in 25 mL of DMF at 20°C. The resulting mixture was stirred for 1 h, after which 2.6 g (10 mmol) of 4-butylphenacyl bromide **3a** was added. After 3-h stirring, 4.0 mL (10 mmol) of 10% aqueous NaOH and 0.85 mL (10 mmol) of allyl bromide **4** were added in succession, and the mixture was stirred for 1 h, left to stand for a day, and then diluted by half with water. The precipitate that formed

Table 2. Crystallographic data for compounds **9** and **17**.

Parameter	**9**	**17**
Brutto formula	$C_{21}H_{16}N_2O_3$	$C_{22}H_{30}N_2O_2$
Molecular weight	344.36	354.48
Crystal dimensions, mm	0.10 × 0.10 × 0.30	0.02 × 0.10 × 0.10
Syngony	Monoclinic	Triclinic
Space groups	$P2_1/c$	P-1
a, A	8.3001(17)	6.4301(13)
b, A	15.000(3)	9.1002(18)
c, A	13.930(3)	17.580(4)
α, deg	90	87.26(3)
β, deg	99.76(3)	82.39(3)
γ, deg	90	76.04(3)
V, A^3	1709.2(6)	989.4(4)
Z	4	2
d_c, g/cm^{-3}	1.338	1.190
$F(000)$	720	384
μ, mm^{-1}	0.190	0.156
$2\theta_{max}$, deg	76.86	71.66
Measured reflections	15269	14541
Unique reflections (R_{int})	3390 (0.053)	3205 (0.061)
Reflections with $I > 2\sigma(I)$	2820	2834
Refined parameters	243	244
R_1; wR_2 [for reflections with $I > 2\sigma(I)$]	0.042; 0.112	0.047; 0.130
R_1; wR_2 (for all measured reflections)	0.052; 0.120	0.052; 0.134
GOF on F^2	1.096	1.096
Extinction coefficient	0.014(2)	0.021(2)
T_{min}; T_{max}	0.940; 0.970	0.975; 0.990

was filtered off, washed with water, ethanol, and hexane. Yield 3.2 g (72%), yellow powder, mp 63–64°C (MeOH). IR spectrum, ν, cm^{-1}: 2202 (C≡N). ^{1}H NMR spectrum, δ, ppm: 0.89 t (3H, Me, J 7.3 Hz), 1.21–1.26 m (2H, CH_2), 1.32 t (3H, Me, J 6.8 Hz), 1.50–1.64 m (2H, CH_2), 2.59 t (2H, CH_2, J 7.7 Hz), 4.08 q (2H, $OC\underline{H_2}Me$, J 6.8 Hz), 4.67 d (2H, $OC\underline{H_2}CH=$, J 5.0 Hz), 5.27 d (1H, $=CH_2$, J_{cis} 10.52 Hz), 5.41 d (1H, $=CH_2$, J_{trans} 17.3 Hz), 5.91–6.17 m (1H, CH=), 7.14 d (1H, H_{arom}, J 8.6 Hz), 7.26 d (2H, H_{arom}, J 7.9 Hz), 7.64 d (1H, H_{arom}, J 8.6 Hz), 7.73 s (1H, H_{arom}), 7.90 d (2H, H_{arom}, J 7.9 Hz), 8.12 s (1H, $H^5_{thiazole}$), 8.21 s (1H, CH=CCN). ^{13}C NMR spectrum, δ, ppm: 14.2, 15.1, 33.5, 35.1, 64.3, 69.3, 96.8, 102.0, 113.8, 114.2, 115.0, 117.6, 118.5, 125.1, 125.7, 126.6 (2C), 129.2 (2C), 131.5, 133.7, 143.3, 145.5, 148.2, 151.6, 156.3, 163.9. HRMS (ESI), *m/z*: found 445.1944 $[M + H]^+$. $C_{27}H_{28}N_2O_2S$. Calculated 445.1871.

Substituted acrylonitriles 7a–7c were synthesized in the same way from aromatic aldehydes **1a** and **1b**, and 0.5 mL (5 mmol) of 1,3-dibromopropane **6**.

(2*E*,2'*E*)-3,3'-(Propane-1,3-diyl)bis[oxy(2-ethoxy-4,1-phenylene)]bis[2-{4-[(4-methylphenyl)phenyl]-1,3-thiazol-2-yl}acrylonitrile] (7a). Yield 2.9 g (75%), bright yellow powder, mp 192–194°C (AcOH). IR spectrum, ν, cm^{-1}: 2215 (C≡N). ^{1}H NMR spectrum, δ, ppm: 1.38 t (6H, 2Me, *J* 6.8 Hz), 2.26 t (2H, CH_2, *J* 6.0 Hz), 2.36 s (6H, 2Me), 4.12 q (4H, 2O$\underline{CH_2}$Me, *J* 6.8 Hz), 4.31 t (4H, 2CH_2O, *J* 6.0 Hz), 7.22 d (2H, H_{arom}, *J* 8.8 Hz), 7.29 d (4H, H_{arom}, *J* 7.7 Hz), 7.68 d (2H, H_{arom}, *J* 8.8 Hz), 7.75 s (2H, $2H^5_{thiazole}$), 7.91 d (4H, H_{arom}, *J* 7.7 Hz), 8.12 s (2H, H_{arom}), 8.24 s (2H, 2CH=CCN). Mass spectrum, *m/z* (I_{rel}, %): 765.7 (100) [*M* + 1]$^+$. Found, %: C 70.50; H 5.11; N 7.23. $C_{45}H_{40}N_4O_4S_2$. Calculated, %: C 70.66; H 5.27; N 7.32. *M* 764.9.

(2*E*,2'*E*)-3,3'-(Propane-1,3-diyl)bis[oxy(4,1-phenylene)]bis[2-{4-[(4-methylphenyl)phenyl]-1,3-thiazol-2-yl}acrylonitrile] (7b). Yield 2.3 g (68%), yellow powder, mp 188–190°C (AcOH). IR spectrum, ν, cm^{-1}: 2200 (C≡N). ^{1}H NMR spectrum, δ, ppm: 2.25 t (2H, CH_2, *J* 6.0 Hz), 2.35 s (6H, 2Me), 4.28 t (4H, 2CH_2O, *J* 6.0 Hz), 7.16 d (4H, H_{arom}, *J* 8.6 Hz), 7.27 d (4H, H_{arom}, *J* 8.0 Hz), 7.90 d (4H, H_{arom}, *J* 8.0 Hz), 8.04 d (4H, H_{arom}, *J* 8.6 Hz), 8.11 s (2H, $2H^5_{thiazole}$), 8.24 s (2H, 2CH=CCN). Mass spectrum, *m/z* (I_{rel}, %): 677.2 (100) [*M* + 1]$^+$. Found, %: C 72.61; H 4.65; N 8.15. $C_{41}H_{32}N_4O_2S_2$. Calculated, %: C 72.76; H 4.77; N 8.28. *M* 676.9.

(2*E*,2'*E*)-3,3'-(Propane-1,3-diyl)bis[oxy(2-methoxy-4,1-phenylene)]bis[2-{4-[(4-methylphenyl)phenyl]-1,3-thiazol-2-yl}acrylonitrile] (7c). Yield 2.5 g (70%), yellow powder, mp 173–175°C (BuOH), it fluoresces under UV irradiation. IR spectrum, ν, cm^{-1}: 2200 (C≡N). ^{1}H NMR spectrum, δ, ppm: 2.23 t (2H, CH_2, *J* 6.0 Hz), 3.79 s (6H, 2MeO), 4.25 t (4H, 2CH_2O, *J* 6.0 Hz), 7.01 d (4H, H_{arom}, *J* 8.8 Hz), 7.15 d (4H, H_{arom}, *J* 8.7 Hz), 7.93 d (4H, H_{arom}, *J* 8.7 Hz), 8.02 d (4H, H_{arom}, *J* 8.8 Hz), 8.04 s (2H, $2H^5_{thiazole}$), 8.22 s (2H, 2CH=CCN). ^{13}C NMR spectrum, δ, ppm: 28.8, 55.7 (2C), 65.1 (2C), 102.1 (2C), 113.8 (2C), 114.7 (4C), 115.7 (4C), 117.5 (2C), 125.6 (2C), 126.7 (2C), 128.1 (4C), 132.6 (4C), 145.0 (2C), 155.6 (2C), 160.0 (2C), 161.9 (2C), 163.2 (2C). HRMS (ESI), *m/z*: found 709.1940 [*M* + H]$^+$. $C_{41}H_{32}N_4O_4S_2$. Calculated 709.1865.

2-Amino-5-oxo-4-(1-phenylethyl)-4,5-dihydropyrano[3,2-*c*]chromene-3-carbonitrile (9). A mixture of 1.33 mL (10 mmol) of 2-phenylpropanal **1c**, 1.6 g (10 mmol) of 4-hydroxycoumarin **8**, 1 g (10 mmol) of cyanothioaceamide **2a**, and 1.1 mL (10 mmol) of *N*-methylmorpholine in 30 mL of DMF was stirred at 20°C for a day and lest to stand for a day. The reaction mixture was diluted by half with water and left to stand for 2 days. The precipitate that formed was filtered off and successively washed with water, ethanol, and hexane. Yield 2.6 g (75%), colorless crystals, mp 219–221°C (*i*-PrOH). IR spectrum, ν, cm^{-1}: 3488, 3252, 3196 (NH_2), 2210 (C≡N), 1719 (C=O), 1643 (δNH_2). ^{1}H NMR spectrum, δ, ppm: 1.12 d (3H, Me, *J* 7.2 Hz), 3.11–3.19 m (1H, $\underline{CH}$Me), 3.61 d (1H, H^4, *J* 3.2 Hz), 7.13–7.25 m (5H, H_{arom}), 7.26 br.s (2H, NH_2), 7.44 t (1H, H_{arom}, *J* 7.6 Hz), 7.48 d (1H, H_{arom}, *J* 7.9 Hz), 7.67 t (1H, H_{arom}, *J* 8.2 Hz), 7.74 d (1H, H_{arom}, *J* 7.9 Hz). ^{13}C NMR spectrum, δ, ppm: 14.1, 43.2, 52.7, 104.85, 104.9, 113.4, 117.0, 119.6, 122.5, 126.9, 128.3 (2C), 128.4 (2C), 133.2, 142.8, 152.6, 155.3, 160.6, 161.3, 170.0. HRMS (ESI), *m/z*: found 343.1088 [*M* – H]$^+$. $C_{21}H_{16}N_2O_3$. Calculated 343.1161.

2,5-Dioxo-4-phenyl-3,5-dihydro-2*H*-chromeno-[4,3-*b*]pyridine-3-carbothioamide (10) was prepared similarly to compound **9** from 1.0 mL (10 mmol) of benzaldehyde **1d**. Yield 2.3 g (77%), light yellow powder, mp 245–247°C (dioxane). IR spectrum, ν, cm^{-1}: 3459, 3316 (NH_2), 1719 (C=O), 1634 (δNH_2), 1181 (C=S). ^{1}H NMR spectrum, δ, ppm: 5.12 s (1H, $H^3_{pyridine}$), 6.83 br.s (2H, NH_2), 7.16 t (1H, H_{arom}, *J* 7.1 Hz), 7.23 t (2H, H_{arom}, *J* 7.4 Hz), 7.34 d (2H, H_{arom}, *J* 7.4 Hz), 7.46 t (2H, H_{arom}, *J* 8.4 Hz), 7.70 t (1H, H_{arom}, *J* 7.6 Hz), 7.99 d (1H, H_{arom}, *J* 7.6 Hz). ^{13}C NMR spectrum, δ, ppm: 36.7, 97.2, 105.2, 114.2, 116.9, 123.1, 125.2, 127.2, 128.4 (2C), 128.7 (2C), 133.2, 142.8, 152.5, 155.9, 157.3, 160.7, 169.7. Mass spectrum, *m/z* (I_{rel}, %): 349.0 [*M* + 1]$^+$. Found, %: C 65.39; H 3.33; N 7.96. $C_{19}H_{12}N_2O_3S$. Calculated, %: C 65.51; H 3.47; N 8.04. *M* 348.4.

2-[2-(7-Allyloxy-2-oxo-2*H*-chromen-3-yl)-2-oxoethylsulfanyl]-6-amino-4-(4-ethoxyphenyl)pyridine-3,5-dicarbonitrile (12). A mixture of 1.4 mL (10 mmol) of 4-ethoxybenzaldehyde **1e**, 2 g (20 mmol) of cyanothioaceamide **2a**, and 3 drops of *N*-methylmorpholine in 30 mL DMF was stirred at 20°C for 30 min, after which 4.0 mL (10 mmol) of 10% aqueous NaOH and 2.8 g (10 mmol) of 7-hydroxy-3-(2-bromoacetyl) coumarin **11** were added in succession. The reaction mixture was stirred for 3 h, left to stand for a day, and diluted by half with water. The precipitate that formed was washed with water, ethanol, and hexane. Yield 4.3 g

(80%), yellow powder, mp 243–245°C (BuOH). IR spectrum, ν, cm^{-1}: 3445, 3318, 3197 (NH_2), 2223 sh (C≡N), 1717, 1695 (C=O), 1644 (δNH_2). ^1H NMR spectrum, δ, ppm: 1.38 t (3H, Me, *J* 6.8 Hz), 4.12 q (2H, O$\underline{CH_2}$Me, *J* 6.8 Hz), 4.68–4.74 m (4H, SCH_2 + O$\underline{CH_2}$CH=), 5.32 d (1H, =CH_2, J_{cis} 10.6 Hz), 5.45 d (1H, =CH_2, J_{trans} 17.3 Hz), 6.01–6.15 m (1H, C$\underline{H}$=CH_2), 7.03–7.16 m (4H, H_{arom}), 7.50 d (2H, H_{arom}, *J* 8.4 Hz), 7.83 br.s (2H, NH_2), 7.93 d (1H, H_{arom}, *J* 8.4 Hz), 8.67 s (1H, $H^4_{coumarin}$). ^{13}C NMR spectrum, δ, ppm: 15.1, 41.0, 63.8, 69.7, 86.3, 93.7, 101.6, 112.7, 114.4, 115.0 (2C), 115.9, 116.1, 118.9, 120.2, 126.1, 130.7 (2C), 132.9, 133.1, 149.0, 157.7, 158.4, 159.6, 160.0, 160.7, 164.4, 166.5, 190.0. Mass spectrum, *m/z* (I_{rel}, %): 539.0 $[M + 1]^+$. Found, %: C 64.52; H 3.97; N 10.32. $C_{29}H_{22}N_4O_5S$. Calculated, %: C 64.67; H 4.12; N 10.40. *M* 538.6.

2-Amino-4-aryl(hetaryl)-7,7-dimethyl-3-[4-aryl-(coumarin-3-yl)-1,3-thi(selen)azol-2-yl]-7,8-dihydro-4*H*-chromen-5(6*H*)-ones (14a–14d) (*general procedure*). Morpholine, 3 drops, was added to a stirred mixture of 10 mmol of aldehyde **1e–1h** and cyanothio-(seleno)acetamide **2a** and **2b** in 30 mL DMF (with compound **2b**, under argon) at 20°C. The resulting mixture was stirred for 30 min, after which 10 mmol of α-bromoketone **3d–3f** was added. After 2-h stirring, 1.4 g (10 mmol) of dimedone **13** and 0.87 mL (10 mmol) of morpholine were added, stirring was continued for an additional 1 h, and the mixture was left to stand for a day, diluted by half with water, and left to stand for 2 days. The precipitate that formed was filtered off and washed with water, ethanol, and hexane.

3-[2-(2-Amino-4-(4-ethoxyphenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4*H*-chromen-3-yl)-1,3-thiazol-4-yl]-2*H*-chromen-2-one (14a). Yield 4.4 g (82%), bright yellow powder, mp 186–188°C (BuOH). IR spectrum, ν, cm^{-1}: 3366, 3140, 2977 (NH_2), 1708, 1661 (C=O), 1607 (δNH_2). ^1H NMR spectrum, δ, ppm: 0.86 s (3H, Me), 1.05 s (3H, Me), 1.25 t (3H, Me, *J* 6.8 Hz), 2.08 d (1H, C^8H_2, ^2J 16.2 Hz), 2.29 d (1H, C^8H_2, ^2J 16.2 Hz), 2.45 d (1H, C^6H_2, ^2J 17.6 Hz), 2.59 d (1H, C^6H_2, ^2J 17.6 Hz), 3.90 q (2H, OCH_2, *J* 6.8 Hz), 4.46 s (1H, H^4_{pyran}), 6.76 d (2H, H_{arom}, *J* 8.3 Hz), 7.18 d (2H, H_{arom}, *J* 8.3 Hz), 7.26–7.49 m (2H, H_{arom}), 7.58 t (1H, H_{arom}, *J* 7.4 Hz), 7.77–7.95 m (3H, NH_2 and H_{arom}), 8.03 s (1H, $H^5_{thiazole}$), 8.76 s (1H, $H^4_{coumarin}$). ^{13}C NMR spectrum, δ, ppm: 15.2, 26.7, 29.3, 32.3, 36.9, 50.5, 63.3, 82.1, 114.2 (2C), 115.0, 115.5, 115.6, 116.3, 119.7, 120.4, 125.1, 129.4, 129.6 (2C), 132.1, 132.7, 136.6, 139.4, 146.7, 152.7, 157.5, 159.3, 161.8, 168.3, 196.1. Mass spectrum, *m/z* (I_{rel}, %): 541.2 (100) $[M + 1]^+$. Found, %: C 68.75; H 5.14; N 5.80. $C_{31}H_{28}N_2O_5S$. Calculated, %: C 68.87; H 5.22; N 5.93. *M* 540.6.

2-Amino-4-(4-bromophenyl)-7,7-dimethyl-3-(4-phenyl-1,3-selenazol-2-yl)-7,8-dihydro-4*H*-chromen-5(6*H*)-one (14b). Yield 4.4 g (79%), yellow powder, mp 115–117°C (EtOH). IR spectrum, ν, cm^{-1}: 3200–3455 (NH_2), 1657 (C=O), 1619 (δNH_2). ^1H NMR spectrum ($CHCl_3$), δ, ppm: 0.96 s (3H, Me), 1.12 s (3H, Me), 2.20 d (1H, C^8H_2, ^2J 16.4 Hz), 2.27 d (1H, C^8H_2, ^2J 16.4 Hz), 2.47 s (2H, C^6H_2), 4.66 s (1H, H^4_{pyran}), 6.75 br.s (2H, NH_2), 7.25–7.48 m (7H, H_{arom}), 7.75 s (1H, $H^5_{selenazole}$), 7.80 d (2H, H_{arom}, *J* 7.3 Hz). ^{13}C NMR spectrum, δ, ppm: 26.8, 29.1, 32.3, 50.4, 84.8, 91.3, 114.2, 115.0, 120.0, 126.6 (2C), 128.1, 129.2 (2C), 131.0 (2C), 131.3 (2C), 135.5, 144.0, 152.4, 154.1, 162.2, 162.8, 173.6, 196.2. Mass spectrum, *m/z* (I_{rel}, %): 555.0 (100) $[M + 1]^+$. Found, %: C 56.22; H 4.05; N 4.93. $C_{26}H_{23}BrN_2O_2Se$. Calculated, %: C 56.34; H 4.18; N 5.05. *M* 554.4.

2-Amino-3-[4-(4-phenylphenyl)-1,3-selenazol-2-yl]-4-(furan-2-yl)-7,7-dimethyl-7,8-dihydro-4*H*-chromen-5(6*H*)-one (14c). Yield 4.2 g (78%), dark red powder, mp 183–185°C (dioxane). IR spectrum, ν, cm^{-1}: 3222–3450 (NH_2), 1655 (C=O), 1623 (δNH_2). ^1H NMR spectrum, δ, ppm: 0.96 s (3H, Me), 1.07 s (3H, Me), 2.18 d (1H, C^8H_2, ^2J 16.1 Hz), 2.34 d (1H, C^8H_2, ^2J 16.1 Hz), 2.52 d (1H, C^6H_2, ^2J 17.6 Hz), 2.60 d (1H, C^6H_2, ^2J 17.6 Hz), 4.63 s (1H, H^4_{pyran}), 6.21 s (1H, H^3_{furan}), 6.28 s (1H, H^4_{furan}), 7.37 t (1H, H_{arom}, *J* 6.8 Hz), 7.42 s (1H, $H^5_{selenazole}$), 7.47 t (2H, H_{arom}, *J* 7.44 Hz), 7.72 t (4H, H_{arom}, *J* 8.6 Hz), 7.95 d (2H, H_{arom}, *J* 8.0 Hz), 8.14 br.s (2H, NH_2), 8.26 s (1H, H^5_{furan}). ^{13}C NMR spectrum, δ, ppm: 26.8, 29.2, 32.4 (2C), 32.9, 50.4, 82.9, 107.6, 110.8, 112.5, 114.3, 127.0 (4C), 127.1 (2C), 128.0, 129.4 (2C), 134.6, 139.7, 140.1, 142.0, 152.6, 153.7, 155.3, 163.3, 173.7, 195.9. Mass spectrum, *m/z* (I_{rel}, %): 543.2 (100) $[M+1]^+$. Found, %: C 66.33; H 4.70; N 4.97. $C_{30}H_{26}N_2O_3Se$. Calculated, %: C 66.42; H 4.83; N 5.16. *M* 542.5.

2-Amino-3-[4-(4-phenylphenyl)-1,3-selenazol-2-yl]-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydro-4*H*-chromen-5(6*H*)-one (14d). Yield 4.3 g (77%), light yellow log-like crystals, mp 189–191°C (dioxane). IR spectrum, ν, cm^{-1}: 3280–3444 (NH_2), 1652 (C=O), 1621 (δNH_2). ^1H NMR spectrum, δ, ppm: 0.91 s (3H, Me), 1.06 s (3H, Me), 2.17 d (1H, C^8H_2, ^2J 16.2 Hz), 2.34 d (1H, C^8H_2, ^2J 16.2 Hz), 2.46 d (1H, C^6H_2, ^2J 17.6 Hz), 2.59 d (1H, C^6H_2, ^2J 17.6 Hz), 4.83 s (1H,

H^4_{pyran}), 6.84 t (1H, $H^4_{thiophene}$, *J* 4.0 Hz), 6.97 d (1H, $H^3_{thiophene}$, *J* 3.0 Hz), 7.24 d (1H, $H^5_{thiophene}$, *J* 5.0 Hz), 7.39 t (1H, H_{arom}, *J* 7.3 Hz), 7.48 t (2H, H_{arom}, *J* 7.3 Hz), 7.71 d (2H, H_{arom}, *J* 8.6 Hz), 7.74 d (2H, H_{arom}, *J* 8.6 Hz), 7.96 d (2H, H_{arom}, *J* 8.2 Hz), 8.18 br.s (2H, NH_2), 8.26 s (1H, $H^5_{selenazole}$). ^{13}C NMR spectrum, δ, ppm: 26.7, 29.2, 32.4, 34.2, 50.4, 85.4, 114.5, 115.3, 125.0, 126.1, 126.9 (3C), 127.0, 127.1, 127.5 (2C), 128.0, 129.4 (3C), 134.2, 139.9, 140.0, 149.2, 152.4, 153.7, 162.4, 173.9, 196.1. Mass spectrum, *m/z* (I_{rel}, %): 559.0 (100) $[M + 2]^+$. Found, %: C 64.49; H 4.62; N 4.93. $C_{30}H_{26}N_2O_2SSe$. Calculated, %: C 64.62; H 4.70; N 5.02. *M* 557.6.

2-Amino-7-(hexyloxy)-4-cyclohexyl-4*H*-chromene-3-carbonitrile (17) was prepared similarly to compounds **14** from 1.21 mL (10 mmol) of cyclohexanecarbaldehyde **1i**, 1.0 g (10 mmol) of cyanothioaceamide **2a**, 1.1 g (10 mmol) of resorcinol **15**, and 1.48 mL (10 mmol) of hexyl iodide **16**. Yield 2.5 g (71%), colorless crystals, mp 135–137°C (AcOH). IR spectrum, ν, cm^{-1}: 3215–3446 (NH_2), 2212 (C≡N), 1633 (δNH_2). ^{1}H NMR spectrum, δ, ppm: 0.83 t (3H, Me, *J* 7.1 Hz), 0.87–1.18 m (4H, H_{aliph}), 1.22–1.32 m (8H, H_{aliph}), 1.49–1.68 m (5H, H_{aliph}), 2.44 –2.48 m (2H, H_{aliph}), 3.22 d (1H, H^4_{pyran}, *J* 3.4 Hz), 3.89 t (2H, OCH_2, *J* 6.5 Hz), 6.44 s (1H, C^8H), 6.66 d (1H, C^6H, *J* 8.5 Hz), 6.79 br.s (2H, NH_2), 7.02 d (1H, C^5H, *J* 8.5 Hz). ^{13}C NMR spectrum, δ, ppm: 14.4, 22.5 (2C), 25.6 (2C), 26.2, 26.4 (2C), 29.0, 29.4, 31.4, 47.2, 53.0, 68.1, 101.5, 111.4, 115.8, 122.1, 129.6, 151.1, 158.5, 162.7. HRMS (ESI), *m/z*: found 355.2380 $[M + H]^+$. $C_{22}H_{30}N_2O_2$. Calculated 355.2307.

FUNDING

The work was financially supported by the 5-100 Russian Academic Excellence Project and Russian Foundation for Basic Research (project nos. 18-53-06006 Az_a and 16-29-10669 ofi_m). X-ray diffraction measurements were performed at the Kurchatov synchrotron radiation source funded by the Ministry of Education and Science of the Russian Federation (project identifier RFMEFI61917X0007).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Pevarello, P., Amici, R., Villa, M., Salom, B., Vulpetti, A., and Varasi, M., US Patent no. 6784198, 2004; *Ref. Zh., Khim*., 2005, no. 05.07-19O.135P.
2. Sanner, M.A., Helal, C.J., and Cooper, C.B., US Patent no. 6720427, 2004; *Ref. Zh., Khim*., 2005, no. 05.04-19O.172P.
3. Bender, W., Betz, U., Kleymann, G., Baumeister, J., Eckenberg, P., Fischer, R., Handke-Ergueden, G., Hendrix, M., Henninger, K., Jensen, A., Keldenich, J., Reefschlöger, J., Schmidf, T., Schneider, U., and Weber, O., FRG Patent Appl. no. 10210319, 2003; *Ref. Zh., Khim*., 2004, no. 04.22-19O.114P.
4. Haap, W., Hölzl, W., Ochs, D., Puchtler, K., and Schnyder, M., EP Patent Appl. no. 1103180, 2001; *Ref. Zh., Khim*., 2001, no. 01.17-19O.327P.
5. Drewe, J.A., Xiong, C.S., and Wang, Y., US Patent no. 6906203, 2005; *Ref. Zh., Khim*., 2006, no. 06.14-19O.57P.
6. Konkay, C.S., Fick, D.B., Cai, S.X., Lan, N.C., and Keana, J.F.W., US Patent no. 6800657, 2004; *Ref. Zh., Khim*., 2005, no. 05.18-19O.110P.
7. Khekhst, A., Bon, M., Kromer, K.T., and Markus, S.A., RF Patent Appl. no. 99108756, 2001; *Ref. Zh., Khim*., 2001, no. 01.14-19O.100P.
8. Darvesh, S., Magee, D., Valenta, Z., and Martin, E., US Patent no. 6436972, 2002; *Ref. Zh., Khim*., 2003, no. 03.07-19O.87P.
9. Crooks, P.A., Dull, G.M., Caldwell, W.S., Bhatti, B.S., Deo, N.M., and Ravard, A., US Patent no. 6624173, 2003; *Ref. Zh., Khim*., 2004, no. 04.11-19O.86P.
10. Dyachenko, I.V. and Dyachenko, V.D., *Russ. J. Org. Chem*., 2016, vol. 52, p. 32. doi 10.1134/S1070428016010061
11. Dyachenko, I.V. and Dyachenko, V.D., *Russ. J. Org. Chem*., 2015, vol. 51, p. 1293. doi 10.1134/S1070428015090146
12. Dyachenko, V.D. and Pugach, Yu.Yu., *Russ. J. Gen. Chem*., 2013, vol. 83, p. 979. doi 10.1134/S1070363213050162
13. Dimrot, K., Wolf, K., and Kroke, H., *J. Lie. Ann. Chem*., 1964, vol. 678, p. 181. doi 10.1002/jlac.19646780119
14. Dyachenko, V.D., Dyachenko, I.V., and Nenaidenko, V.G., *Russ. Chem. Rev*., 2018, vol. 87, p. 1. doi 10.1070/RCR4760
15. Antipin, I.S., Kazymova, M.A., Kuznetsov, M.A., Vasilyev, A.V., Ishchenko, M.A., Kiryushkin, A.A., Kuznetsova, L.M., Makarenko, S.V., Ostrovskii, V.A., Petrov, M.L., Solod, O.V., Trishin, Yu.G., Yakovlev, I.P., Nenaidenko, V.G., Beloglazkina, E.K., Beletskaya, I.P., Ustynyuk, Yu.A., Solov'ev, P.A., Ivanov, I.V., Malina, E.V., Sivova, N.V., Negrebetskii, V.V., Baukov, Yu.I., Pozharskaya, N.A., Traven', V.F., Shchekotikhin, A.E., Varlamov, A.V., Borisova T.N., Lesina, Yu.A., Krasnokutskaya, E.A., Rogozhnikov, S.I., Shurov, S.N., Kustova, T.P., Klyuev, M.V., Khelevina, O.G., Stuzhin, P.A., Fedorov, A.Yu., Gushchin, A.V., Dodonov, V.A., Kolobov, A.V., Plakhtinskii, V.V., Orlov, V.Yu., Kriven'ko, A.P.,

Fedotova, O.V., Pchelintseva, N.V., Charushin, V.N., Chupakhin, O.N., Klimochkin, Yu.N., Klimochkina, A.Yu., Kuryatnikov, V.N., Malinovskaya, Yu.A., Levina, A.S., Zhuravlev, O.E., Voronchikhina, L.I., Fisyuk, A.S., Aksenov, A.V., Aksenov, N.A., and Aksenova, I.V., *Russ. J. Org. Chem*., 2017, vol. 53, p. 1275. doi 10.1134/S1070428017090019

16. Konovalov, A.I., Antipin, I.S., Burilov, V.A., Madzhidov, T.I., Kurbangalieva, A.R., Nemtarev, A.V., Solovieva, S.E., Stoikov, I.I., Mamedov, V.A., Zakharova, L.Ya., Gavrilova, E.L., Sinyashin, O.G., Balova, I.A., Vasilyev, A.V., Zenkevich, I.G., Krasavin, M.Yu., Kuznetsov, M.A., Molchanov, A.P., Novikov, M.S., Nikolaev, V.A., Rodina, L.L., Khlebnikov, A.F., Beletskaya, I.P., Vatsadze, S.Z., Gromov, S.P., Zyk, N.V., Lebedev, A.T., Lemenovskii, D.A., Petrosyan, V.S., Nenaidenko, V.G., Negrebetskii, V.V., Baukov, Yu.I., Shmigol', T.A., Korlyukov, A.A., Tikhomirov, A.S., Shchekotikhin, A.E., Traven', V.F., Voskresenskii, L.G., Zubkov, F.I., Golubchikov, O.A., Semeikin, A.S., Berezin, D.B., Stuzhin, P.A., Filimonov, V.D., Krasnokutskaya, E.A., Fedorov, A.Yu., Nyuchev, A.V., Orlov, V.Yu., Begunov, R.S., Rusakov, A.I., Kolobov, A.V., Kofanov, E.R., Fedotova, O.V., Egorova, A.Yu., Charushin, V.N., Chupakhin, O.N., Klimochkin, Yu.N., Osyanin, V.A., Reznikov, A.N., Fisyuk, A.S., Sagitullina, G.P., Aksenov, A.V., Aksenov, N.A., Grachev, M.K., Maslennikova, V.I., Koroteev, M.P., Brel', A.K., Lisina, S.V., Medvedeva, S.M., Shikhaliev, Kh.S., Suboch, G.A., Tovbis, M.S., Mironovich, L.M., Ivanov, S.M., Kurbatov, S.V., Kletskii, M.E., Burov, O.N., Kobrakov, K.I., and Kuznetsov, D.N., *Russ. J. Org. Chem*., 2018, vol. 54, p. 157. doi 10.1134/S107042801802001X
17. Dyachenko, V.D., Bityukova, O.S., and Dyachenko, A.D., *Russ. J. Org. Chem*., 2011, vol. 47, p. 1335. doi 10.1134/S1070428011090132
18. Dyachenko, V.D., *Russ. J. Org. Chem*., 2011, vol. 47, p. 1535. doi 10.1134/S1070428011100150
19. Krivokolysko, S.G., Dyachenko, V.D., and Litvinov, V.P., *Chem. Heterocycl. Comp*., 2001, vol. 37, p. 1114. doi 10.1023/A:1013231800661
20. Dyachenko, V.D. and Chernega, A.N., *Russ. J. Org. Chem*., 2006, vol. 42, p. 567. doi 10.1134/S1070428006040142
21. Dyachenko, V.D., *Russ. J. Gen. Chem*., 2006, vol. 76, p. 282. doi 10.1134/S1070363206020216
22. Krivokolysko, S.G., Dyachenko, V.D., Chernega, A.N., and Litvinov, V.P., *Russ. Chem. Bull*., 2000, vol. 49, p. 736. doi 10.1007/BF02495493
23. Abd-El-Aziz, A.S., Egrody, M., Bedair, A.H., Corkery, T., and Ata, A., *Heterocycles*, 2004, vol. 63, p. 1793. doi 10.3987/COM-04-10089
24. Battye, T.G., Kontogiannis, L., Johnson, O., Powell, H.R., and Leslie, A.G.W., *Acta Cryst*., 2011, vol. D67, p. 271. doi 10.1107/S0907444910048675
25. Evans, P., *Acta Cryst*., 2006, vol. D62, p. 72. doi 10.1107/S0907444905036693
26. Sheldrick, G.M., *Acta Cryst*., 2015, vol. C71, p. 3. doi 10.1107/S2053229614024218