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# Synthesis of 7-Iodo(arylsulfanyl)methyl-7,8-dihydro-[1,3]thiazolo[2,3-*i*]purinium Pentaiodide (Perchlorates) and Their Transformation into 4-Amino-5-(1,3-thiazol-2-yl)imidazole Derivatives

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**Abstract**—Intramolecular electrophilic cyclization of 6-allylsulfanylpurine by the action of iodine and arenesulfenyl chlorides gave 7-iodomethyl-7,8-dihydro[1,3]thiazolo[2,3-*i*]purin-6-ium pentaiodide and 7-arylsulfanylmethyl-7,8-dihydro[1,3]thiazolo[2,3-*i*]purin-6-ium perchlorates, respectively. 7-Iodomethyl-7,8-dihydro-[1,3]thiazolo[2,3-*i*]purin-6-ium iodide reacted with sodium and potassium alkoxides to produce alkyl *N*-[5-(4-methyl-1,3-thiazol-2-yl)-1*H*-imidazol-4-yl]formimidates, and its reaction with secondary cyclic amines afforded 5-(4-methyl-1,3-thiazol-2-yl)-*N*-[morpholin-4-yl(or piperidin-1-yl)methylidene]-1*H*-imidazol-4-amines. Successive treatment of 7-arylsulfanylmethyl-7,8-dihydro[1,3]thiazolo[2,3-*i*]purin-6-ium perchlorates with sodium acetate and morpholine led to the formation of 5-(4-arylsulfanylmethyl-4,5-dihydro-1,3-thiazol-2-yl)-*N*-(morpholin-4-ylmethylidene)-1*H*-imidazol-4-amines.

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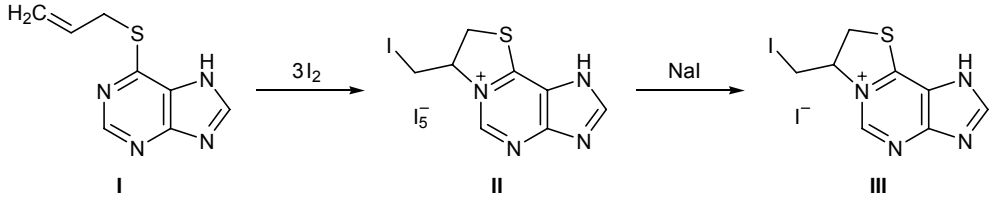
Intramolecular electrophilic cyclization of 2-allylsulfanylpirimidines [1, 2] and their fused analogs [3–5] provides a convenient method for the synthesis of [1,3]thiazolo[3,2-*a*]pyrimidine derivatives. On the other hand, analogous transformations of compounds containing an allylsulfanyl group in position *4* of the pyrimidine ring, e.g., 4-allylsulfanylquinazolines [6, 7] or 6-allylsulfanylpurines [8] were not reported. Taking into account pronounced therapeutic effect of 6-sulfanylpurine [9] and its *S*-alkyl derivatives [10–13], their chemical modification seems to be important from the viewpoints of both synthetic and biological applications.

Since the first synthesis of representatives of the 7,8-dihydro[1,3]thiazolo[2,3-*i*]purine heterocyclic system by condensation of 6-sulfanylpurine with 1,2-dihaloethanes [12, 13], these compounds permanently attract researchers' attention [14, 15]. Other versions of their synthesis have not found practical application. Therefore, we believed it reasonable to use for this purpose intramolecular electrophilic cyclization of 6-allylsulfanylpurine (**I**) by the action of iodine and arenesulfenyl chlorides.

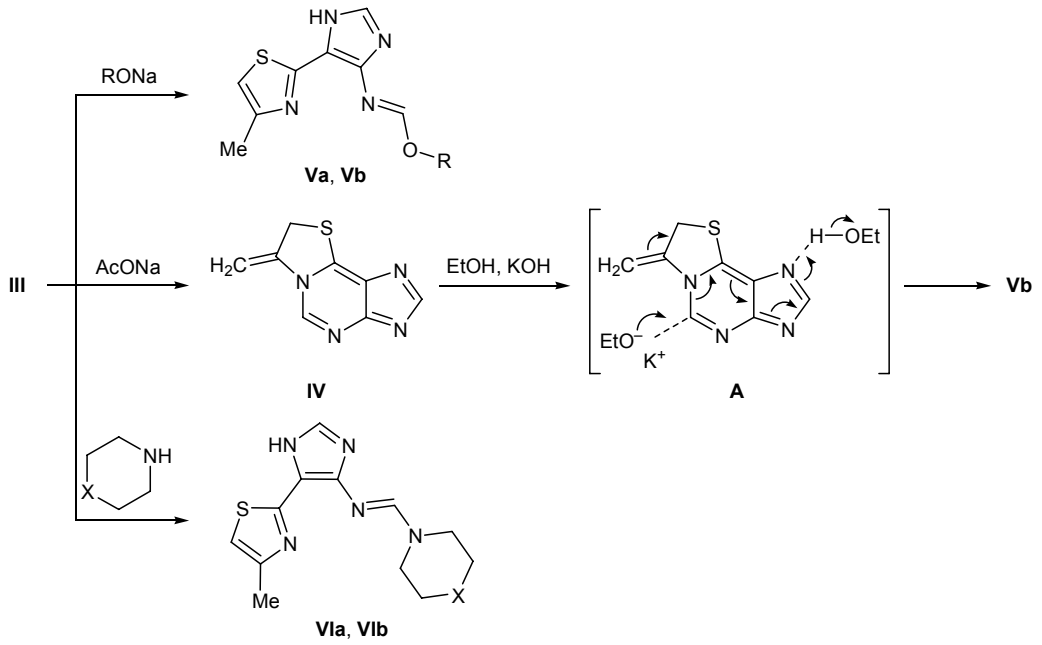
Compound **I** reacted with 3 equiv of iodine in chloroform at room temperature to give 7-iodomethyl-7,8-dihydro[1,3]thiazolo[2,3-*i*]purin-6-ium pentaiodide (**II**) in quantitative yield as a result of selective intramolecular cyclization. The subsequent treatment of **II** with sodium iodide in acetone quantitatively afforded the corresponding iodide **III** (Scheme 1). The structure

**Scheme 1.**




**I** **II** **III**

**Scheme 2.**




**V**, R = Me (**a**), Et (**b**); **VI**, X = $CH_2$ (**a**), O (**b**).

of **II** and **III** is consistent with the IR and NMR data. The IR spectra of **II** and **III** contained an absorption band in the region 1630–1610 $cm^{-1}$ due to stretching vibrations of the iminium fragment, and their $^1H$ NMR spectra displayed multiplet signals from protons in the dihydrothiazole ring (δ 3.83–5.84 ppm) and singlets from 2-H and 5-H at δ 8.97 and 9.47–9.48 ppm, respectively.

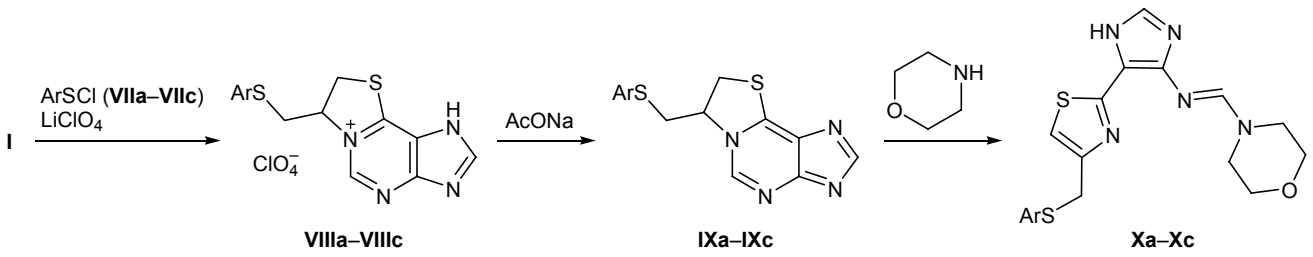
Molecule **III** possesses two electrophilic centers and is a convenient model for studying reactions with nucleophiles. By treatment of **III** with sodium acetate in ethanol at room temperature we obtained 7-methylidene-7,8-dihydro[1,3]thiazolo[2,3-*i*]purine (**IV**) (Scheme 2). The reactions of **III** with sodium methoxide or ethoxide followed a much more complex pattern and unexpectedly resulted in the formation of alkyl *N*-[5-(4-methyl-1,3-thiazol-2-yl)-1*H*-imidazol-4-yl]-formimidates **Va** and **Vb**. Most probably, compound **IV** was initially formed as intermediate. This assumption was confirmed by the isolation of **Vb** when 7-methylidene derivative **IV** was heated to 60°C in ethanol in the presence of potassium hydroxide. The process is most likely to involve opening of the pyrimidine ring in intermediate **A** by the action of alkoxide ion and simultaneous or subsequent 1,3-prototropic shift in the dihydrothiazole fragment.

The described reaction may be regarded as a new version of fragmentation of pyrimidine ring in the thiazolopurine system, which could ensure a novel synthetic approach to 4-amino derivatives of biheterocyclic thiazolylimidazole ensemble. Monthomery et al. [13] previously described cleavage of the thiazole ring in 7,8-dihydro-3*H*-thiazolo[2,3-*i*]purinium bromides in reactions with benzenethiols.

We found that this reaction is more general. Thiazolopurinium iodide **III** reacted with excess cyclic secondary amines (piperidine and morpholine) at room temperature to produce 4-amino-5-thiazolylimidazole derivatives **VIa** and **VIb** in high yield. Compounds **Va**, **Vb**, **VIa**, and **VIb** showed in the $^1H$ NMR spectra singlets from protons in the thiazole and imidazole rings at δ 6.98–7.18 and 8.40–8.62 ppm, respectively, and a singlet at δ 7.43–7.58 ppm from the formamidine CH proton. The exocyclic amidine fragment gave a singlet at $\delta_C$ 151–156 ppm in the $^{13}C$ NMR spectra.

The structure of compound **VIa** was unambiguously proved by X-ray analysis (Figs. 1, 2). The thiazole and imidazole rings in molecule **VIa** are characterized by standard geometric parameters. Both heterorings are planar within 0.005 and 0.0027 Å, respectively, and the dihedral angle between their planes is 11.1(2)°. The $N^4$=$C^8$ double bond length [1.288(3) Å] does not differ from the corresponding standard value, whereas the formally single $N^4$–$C^7$ [1.383(3) Å] and $N^5$–$C^8$ bonds [1.341(3) Å] are appreciably shortened so that they approach those typical of conjugated or

**Scheme 3.**




Ar = Ph (**a**), 4-$MeC_6H_4$ (**b**), 4-$O_2NC_6H_4$ (**c**).

heteroaromatic systems. The sum of the bond angles at the $N^5$ atom is 358.2(2)°, indicating electron density delocalization over the molecule. Molecules **VIa** in crystal (Fig. 2) form infinite chains due to hydrogen bonding $N^2$–$H^{2N}\cdots N^{3A}$ along the *a* crystallographic axis [$N^2$–$H^{2N}$ 0.93(3), $N^2\cdots N^{3A}$ 2.840(3) Å, $\angle N^2H^{2N}N^{3A}$ 170(2)°; here, the superscript "*A*" refers to a nitrogen atom related to the base atoms through the symmetry operation $x - 5$, $1.5 - y$, $-z$.

6-Allylsulfanylpurine **I** was also subjected to intramolecular cyclization by the action of arenesulfenyl chlorides **VIIa**–**VIIc** in acetic acid in the presence of an equimolar amount of lithium perchlorate [16, 17] (Scheme 3). As a result, we isolated 85–89% of 7-arylsulfanylmethyl-7,8-dihydro[1,3]thiazolo[2,3-*i*]-purin-6-ium perchlorates **VIIIa**–**VIIIc**. Treatment of the latter with sodium acetate in ethanol smoothly afforded free bases **IXa**–**IXc** which reacted with excess morpholine under mild conditions to give new imidazoles **Xa**–**Xc** containing a formamidine fragment in position *4* and a 4-(arylsulfanylmethyl)dihydrothiazolyl substituent in position *5*. The structure of **Xa**–**Xc** was confirmed by their $^1H$ and $^{13}C$ NMR spectra which contained signals at δ 7.46–7.48 ppm and $\delta_C$ 152 ppm from the formamidine CH fragment.

## EXPERIMENTAL

The IR spectra were recorded in KBr on a UR-20 spectrometer. The $^1H$ and $^{13}C$ NMR spectra were measured on a Bruker Avance DRX-500 spectrometer at 400 and 125.75 MHz, respectively, using tetramethylsilane as internal reference. The mass spectra of **VIa**, **VIb**, **IXa**–**IXc**, and **Xb** were obtained on an Agilent 1100/DAD/HSD/VLG 119562 instrument.

6-Allylsulfanyl-7*H*-purine (**I**) was synthesized according to the procedure described in [8].

The X-ray diffraction data for compound **VIa** were acquired at 173 K from a 0.14×0.18×0.35-mm single crystal on a Bruker Smart Apex II diffractometer (λMo$K_\alpha$ irradiation, graphite monochromator, $\theta_{max}$ = 28.36°, spherical segment $-9 \le h \le 12$, $-14 \le k \le 14$, $-18 \le l \le 19$). $C_{13}H_{17}N_5S$, *M* 275.38; rhombic crystals, space group $P2_12_12_1$; unit cell parameters: $a$ = 9.2666(5), $b$ = 10.8871(5), $c$ = 14.3498(6) Å; $V$ =

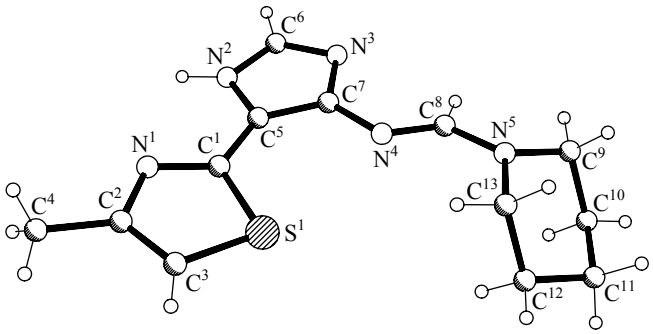



**Fig. 1.** Structure of the molecule of 5-(4-methyl-1,3-thiazol-2-yl)-*N*-[(piperidin-1-yl)methylidene]-1*H*-imidazol-4-amine (**VIa**) according to the X-ray diffraction data. Principal bond lengths (Å) and bond angles (deg): $S^1$–$C^1$ 1.729(2), $N^1$–$C^1$ 1.316(3), $N^1$–$C^2$ 1.378(3), $C^2$–$C^3$ 1.345(4), $S^1$–$C^3$ 1.711(3), $C^1$–$C^5$ 1.432(3), $N^2$–$C^5$ 1.388(3), $N^2$–$C^6$ 1.333(3), $N^3$–$C^6$ 1.323(3), $N^3$–$C^7$ 1.376(3), $C^5$–$C^7$ 1.381(3); $N^1C^1S^1$ 114.15(18), $C^1N^1C^2$ 110.8(2), $C^3C^2N^1$ 114.9(2), $C^2C^3S^1$ 111.1(2), $C^3S^1C^1$ 89.01(13), $C^6N^2C^5$ 106.8(2), $N^3C^6N^2$ 113.1(2), $C^6N^3C^7$ 104.8(2), $N^3C^7C^5$ 109.9(2), $C^7C^5N^2$ 105.3(2), $C^8N^4C^7$ 117.0(2), $N^4C^8N^5$ 123.5(3).

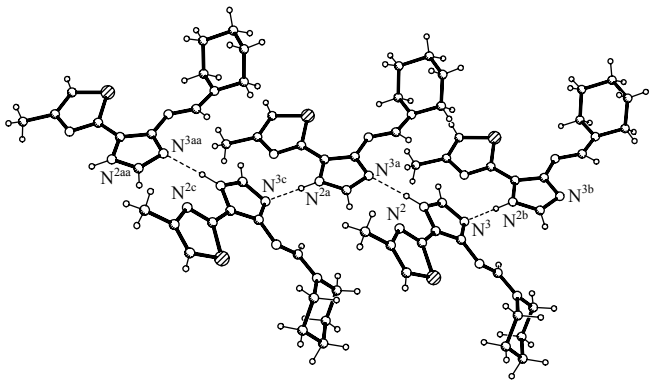



**Fig. 2.** Hydrogen bond chains in the crystalline structure of compound **VIa** along the *a* crystallographic axis.

1447.70(12) Å$^3$; $Z$ = 4; $d_{calc}$ = 1.263 g/cm$^3$; μ = 0.218 mm$^{-1}$; $F$(000) = 584. Total of 17399 reflection intensities were measured, 3591 of which were independent (averaging $R$-factor 0.0734). A correction for absorption was introduced by the multiscan method using SADABS program ($T_{min}/T_{max}$ = 0.72674). The structure was solved by the direct method and was refined by the least-squares procedure using Bruker SHELXTL software package [18]. All non-hydrogen atoms were refined in anisotropic approximation. Hydrogen atoms were visualized objectively, and their positions were refined in isotropic approximation. The refinement was performed from 2161 reflections with $I > 2\sigma(I)$ {240 variables, 9.0 reflections per variable; weight scheme $\omega = 1/[\sigma^2(Fo^2) + (0.0373R)^2]$, where $R = (Fo^2 + 2Fc^2)/3$}. The final divergence factors were $R_1(F) = 0.0501$, $wR_2(F^2) = 0.0805$ for reflections with $I > 2\sigma(I)$ and $R_1(F) = 0.1082$, $wR_2(F^2) = 0.0968$ for all reflections; goodness of fit 0.993; Flack parameter –0.04(9). The residual electron density from the Fourier difference series after last iteration was 0.19 and –0.27 $e$/Å$^3$. The set of crystallographic data for compound **VIa** was deposited to the Cambridge Crystallographic Data Centre (entry no. CCDC 880940).

**7-Iodomethyl-7,8-dihydro[1,3]thiazolo[2,3-*i*]-purin-6-ium pentaiodide (II).** A solution of 3.81 g (15 mmol) of iodine in 300 ml of chloroform was added at room temperature to a suspension of 0.96 g (5 mmol) of compound **I** in 20 ml of chloroform, and the mixture was stirred for 48 h. The black crystalline solid was filtered off, washed with 30 ml of hexane, and dried in air. Yield 4.72 g (99%), mp 158–160°C. IR spectrum, ν, cm$^{-1}$: 1610, 1580, 1490, 1420, 1260, 920. $^1$H NMR spectrum, δ, ppm: 3.83–3.87 m (1H, CH), 3.92–3.93 m (2H, $CH_2$), 4.24–4.31 m (1H, CH), 5.71–5.84 m (1H, CH), 8.97 s (1H, 2-H), 9.47 s (1H, 5-H). Found, %: C 10.02; H 0.83; I 79.56; N 5.81; S 3.31. $C_8H_8I_6N_4S$. Calculated, %: C 10.08; H 0.85; I 79.84; N 5.87; S 3.36.

**7-Iodomethyl-7,8-dihydro[1,3]thiazolo[2,3-*i*]-purin-6-ium iodide (III).** A solution of 0.90 g (6 mmol) of sodium iodide in 20 ml of acetone was added under stirring to a solution of 1.91 g (2 mmol) of compound **II** in 30 ml of acetone. After a time, the yellow crystalline solid was filtered off, washed with acetone, and dried in air. Yield 0.87 g (98%), mp 223–225°C. IR spectrum, ν, cm$^{-1}$: 3030, 1630, 1540, 1500, 1400, 1360, 1250, 1220, 1190, 1120, 1040. $^1$H NMR spectrum, δ, ppm: 3.84–3.88 m (1H, CH), 3.93–3.95 m (2H, $CH_2$), 4.26–4.32 m (1H, CH), 5.78–5.82 m (1H, CH), 8.97 s (1H, 2-H), 9.48 s (1H, 5-H). Found, %: C 21.51; H 1.77; I 56.86; N 12.47; S 7.13. $C_8H_8I_2N_4S$. Calculated, %: C 21.54; H 1.81; I 56.90; N 12.56; S 7.19.

**7-Methylidene-7,8-dihydro[1,3]thiazolo[2,3-*i*]-purine (IV).** A mixture of 0.45 g (1 mmol) of compound **III** and 0.16 g (2 mmol) of sodium acetate in 50 ml of ethanol was stirred for 48 h at room temperature. The precipitate was filtered off, washed with water and ethanol, and dried in air. Yield 0.12 g (63%), mp >320°C. IR spectrum, ν, cm$^{-1}$: 1640, 1600, 1500, 1420, 1400, 1360, 1290, 1240, 1150, 1020. $^1$H NMR spectrum, δ, ppm: 4.56 m (2H, $CH_2$), 5.48 m and 6.12 m (1H each, $=CH_2$), 8.38 s (1H, 2-H), 9.41 s (1H, 5-H). Found, %: C 50.44; H 3.11; N 29.37; S 16.74. $C_8H_6N_4S$. Calculated, %: C 50.51; H 3.18; N 29.45; S 16.86.

**Alkyl *N*-[5-(4-methyl-1,3-thiazol-2-yl)-1*H*-imidazol-4-yl]formimidates Va and Vb (*general procedures*).** *a*. Compound **III**, 0.45 g (1 mmol), was added to a solution of sodium alkoxide prepared from 0.07 g (3 mmol) of metallic sodium and 30 ml of methanol or ethanol. The mixture was stirred for 6 h and evaporated under reduced pressure, and the residue was treated with diethyl ether. The ether extract was washed with water, dried over $MgSO_4$, and evaporated under reduced pressure, and the solid residue was filtered off and washed with hexane.

*b*. A mixture of 0.06 g (1 mmol) of potassium hydroxide and 0.19 g (1 mmol) of compound **IV** in 30 ml of ethanol was heated for 10 min at 60°C. The solvent was removed under reduced pressure, and the precipitate was filtered off, washed with water, and dried.

**Methyl *N*-[5-(4-methyl-1,3-thiazol-2-yl)-1*H*-imidazol-4-yl]formimidate (Va).** Yield 0.14 g (63%) (*a*), mp 132–134°C. IR spectrum, ν, cm$^{-1}$: 1640, 1590, 1530, 1420, 1350, 1290, 1230, 1180, 1110, 1020, 970, 930. $^1$H NMR spectrum, δ, ppm: 2.40 s (3H, $CH_3$), 3.91 s (3H, $OCH_3$), 7.18 s (1H, 5′-H), 7.58 s (1H, N=CH), 8.62 s (1H, 2-H), 12.88 s (1H, NH). $^{13}$C NMR spectrum, $\delta_C$, ppm: 16.71 ($CH_3$), 53.76 ($OCH_3$), 113.42 ($C^{5'}$), 116.66 ($C^4$), 134.85 ($C^2$), 143.81 ($C^5$), 151.13 ($C^{4'}$), 155.76 ($C^{2'}$), 156.70 (N=CH). Found, %: C 48.55; H 4.44; N 25.19; S 14.35. $C_9H_{10}N_4OS$. Calculated, %: C 48.63; H 4.53; N 25.21; S 14.43.

**Ethyl *N*-[5-(4-methyl-1,3-thiazol-2-yl)-1*H*-imidazol-4-yl]formimidate (Vb).** Yield 0.16 g (66%) (*a*), 0.16 g (67%) (*b*); mp 138–139°C. IR spectrum, ν, cm$^{-1}$: 3130, 3020, 2880, 1630, 1590, 1520, 1440, 1350, 1290, 1220, 1110, 1020. $^1$H NMR spectrum, δ, ppm: 1.37 t (3H, $CH_3$, $J$ = 6.8 Hz), 2.39 s (3H, $CH_3$), 4.38 q

(2H, $CH_2$, $J$ = 6.8 Hz), 7.12 s (1H, 5′-H), 7.57 s (1H, N=CH), 8.58 s (1H, 2-H), 12.85 s (1H, NH). $^{13}$C NMR spectrum, $\delta_C$, ppm: 14.00 (**C**$H_3CH_2$), 16.69 (4′-$CH_3$), 62.36 ($OCH_2$), 113.40 ($C^{5'}$), 116.23 ($C^4$), 134.93 ($C^2$), 143.72 ($C^5$), 151.10 ($C^{4'}$), 155.71 ($C^{2'}$), 156.12 (N=CH). Found, %: C 50.76; H 5.04; N 23.61; S 13.42. $C_{10}H_{12}N_4OS$. Calculated, %: C 50.83; H 5.12; N 23.71; S 13.57.

**5-(4-Methyl-1,3-thiazol-2-yl)-*N*-(dialkylaminomethylidene)-1*H*-imidazol-4-amines VIa and VIb (*general procedure*).** A mixture of 0.45 g (1 mmol) of compound **III** and 15 ml of piperidine or morpholine was stirred for 20 h at room temperature. Excess amine was distilled off, and the solid residue was filtered off, washed with water, dried, and recrystallized from ethanol.

**5-(4-Methyl-1,3-thiazol-2-yl)-*N*-(piperidin-1-ylmethylidene)-1*H*-imidazol-4-amine (VIa).** Yield 0.17 g (63%), mp 194–195°C. IR spectrum, ν, $cm^{-1}$: 2940, 2860, 1620, 1580, 1520, 1420, 1360, 1340, 1290, 1250, 1210, 1100, 1020, 1000. $^1$H NMR spectrum, δ, ppm: 1.56 m (4H, $CH_2$), 1.64 m (2H, $CH_2$), 2.36 s (3H, $CH_3$), 3.40 m (2H, $CH_2$), 3.69 m (2H, $CH_2$), 6.96 s (1H, 5′-H), 7.43 s (1H, N=CH), 8.40 s (1H, 2-H), 12.41 s (1H, NH). $^{13}$C NMR spectrum, $\delta_C$, ppm: 16.78 ($CH_3$), 24.16 ($CH_2$), 24.54 ($CH_2$), 26.29 ($CH_2$), 42.61 ($CH_2$), 49.59 ($CH_2$), 111.62 ($C^{5'}$), 113.66 ($C^4$), 134.10 ($C^2$), 148.15 ($C^5$), 150.45 ($C^{4'}$), 152.03 (N=CH), 156.93 ($C^{2'}$). Mass spectrum: $m/z$ 276 $[M + 1]^+$. Found, %: C 56.56; H 6.16; N 25.38; S 11.58. $C_{13}H_{17}N_5S$. Calculated, %: C 56.70; H 6.22; N 25.43; S 11.64. $M$ 275.37.

**5-(4-Methyl-1,3-thiazol-2-yl)-*N*-(morpholin-4-ylmethylidene)-1*H*-imidazol-4-amine (VIb).** Yield 0.23 g (84%), mp 111–113°C. IR spectrum, ν, $cm^{-1}$: 3020, 1620, 1580, 1520, 1440, 1350, 1300, 1240, 1190, 1180, 1120, 1030, 920. $^1$H NMR spectrum, δ, ppm: 2.36 s (3H, $CH_3$), 3.48 m (2H, $CH_2$), 3.67 m (6H, $CH_2$), 7.02 s (1H, 5′-H), 7.47 s (1H, N=CH), 8.44 s (1H, 2-H), 12.51 s (1H, NH). $^{13}$C NMR spectrum, $\delta_C$, ppm: 16.77 ($CH_3$), 42.80 ($CH_2$), 48.44 ($CH_2$), 65.45 ($CH_2$), 66.57 ($CH_2$), 111.91 ($C^{5'}$), 113.60 ($C^4$), 134.43 ($C^2$), 148.27 ($C^5$), 150.53 ($C^{4'}$), 151.86 (N=CH), 156.38 ($C^{2'}$). Mass spectrum: $m/z$ 278 $[M + 1]^+$. Found, %: C 51.88; H 5.33; N 25.16; S 11.42. $C_{12}H_{15}N_5OS$. Calculated, %: C 51.97; H 5.45; N 25.25; S 11.56. $M$ 277.35.

**7-Arylsulfanylmethyl-7,8-dihydro[1,3]thiazolo[2,3-*i*]purin-6-ium perchlorates VIIIa–VIIIc (*general procedure*).** A solution of 2.1 mmol of arenesulfenyl chloride **VIIa**–**VIIc** in 10 ml of acetic acid was added at 15–20°C to a suspension of 0.38 g (2 mmol) of compound **I** and 0.22 g (2 mmol) of $LiClO_4$ in 20 ml of acetic acid. The mixture was stirred for 5–6 h, left to stand for 12 h, and evaporated, and the precipitate was filtered off, washed with diethyl ether on a filter, and dried in air.

**7-[(Phenylsulfanyl)methyl]-7,8-dihydro[1,3]thiazolo[2,3-*i*]purin-6-ium perchlorate (VIIIa).** Yield 0.68 g (85%), mp 107–109°C. IR spectrum, ν, $cm^{-1}$: 1620, 1570, 1500, 1410, 1350, 1260, 1120, 1090, 920, 880. $^1$H NMR spectrum, δ, ppm: 3.71–3.88 m (2H, $CH_2$), 3.97–4.00 m (1H, CH), 4.23–4.28 m (1H, CH), 5.77–5.83 m (1H, CH), 7.09 t (1H, $H_{arom}$, $J$ = 7.6 Hz), 7.17 t (2H, $H_{arom}$, $J$ = 7.6 Hz), 7.35 d (2H, $H_{arom}$, $J$ = 8.0 Hz), 8.89 s (1H, 2-H), 9.31 s (1H, 5-H). $^{13}$C NMR spectrum, $\delta_C$, ppm: 36.11 ($C^8$), 36.14 ($CH_2S$), 67.82 ($C^7$), 126.54 ($C_{arom}$), 128.88 (2C, $C_{arom}$), 128.92 (2C, $C_{arom}$), 133.17 ($C_{arom}$), 145.70 ($C^2$), 149.32 ($C^5$), 151.73 ($C^{9b}$), 158.55 ($C^{3a}$), 194.06 ($C^{9a}$). Found, %: C 41.88; H 3.22; Cl 8.79; N 13.94; S 15.91. $C_{14}H_{13}ClN_4O_4S_2$. Calculated, %: C 41.95; H 3.27; Cl 8.84; N 13.98; S 16.00.

**7-[(4-Methylphenylsulfanyl)methyl]-7,8-dihydro[1,3]thiazolo[2,3-*i*]purin-6-ium perchlorate (VIIIb).** Yield 0.74 g (89%), mp 104–106°C. IR spectrum, ν, $cm^{-1}$: 3050, 2970, 1620, 1580, 1500, 1410, 1360, 1260, 1120, 920, 890. $^1$H NMR spectrum, δ, ppm: 2.16 s (3H, $CH_3$), 3.62–3.89 m (2H, $CH_2$), 3.95–4.00 m (1H, CH), 4.21–4.28 m (1H, CH), 5.76–5.84 m (1H, CH), 6.93 d (2H, $H_{arom}$, $J$ = 7.5 Hz), 7.21 d (2H, $H_{arom}$, $J$ = 8.4 Hz), 8.91 s (1H, 2-H), 9.28 s (1H, 5-H). Found, %: C 43.36; H 3.62; Cl 8.49; N 13.41; S 15.32. $C_{15}H_{15}ClN_4O_4S_2$. Calculated, %: C 43.42; H 3.64; Cl 8.55; N 13.50; S 15.46.

**7-[(4-Nitrophenylsulfanyl)methyl]-7,8-dihydro[1,3]thiazolo[2,3-*i*]purin-6-ium perchlorate (VIIIc).** Yield 0.76 g (87%), mp 205–207°C. IR spectrum, ν, $cm^{-1}$: 3130, 1630, 1580, 1500, 1410, 1340, 1260, 1110, 1090, 1060. $^1$H NMR spectrum, δ, ppm: 3.85–4.02 m (3H, CH, $CH_2$), 4.25–4.30 m (1H, CH), 5.84–5.89 m (1H, CH), 7.62 d (2H, $H_{arom}$, $J$ = 8.4 Hz), 8.03 d (2H, $H_{arom}$, $J$ = 9.2 Hz), 8.92 s (1H, 2-H), 9.39 s (1H, 5-H). $^{13}$C NMR spectrum, $\delta_C$, ppm: 34.52 ($C^8$), 36.56 (7-$CH_2$), 67.33 ($C^7$), 123.71 (2C, $C_{arom}$), 127.85 (2C, $C_{arom}$), 143.99 ($C_{arom}$), 145,14 ($C_{arom}$), 145.91 ($C^2$), 149.50 ($C^5$), 151.91 ($C^{9b}$), 158.58 ($C^{3a}$), 194.10 ($C^{9a}$). Found, %: C 37.56; H 2.67; Cl 7.86; N 15.63; S 14.31. $C_{14}H_{12}ClN_5O_6S_2$. Calculated, %: C 37.71; H 2.71; Cl 7.95; N 15.71; S 14.38.

**7-Arylsulfanylmethyl-7,8-dihydro[1,3]thiazolo-[2,3-*i*]purines IXa–IXc (*general procedure*).** A mixture of 1 mmol of compound **VIIIa–VIIIc** and 0.16 g (2 mmol) of sodium acetate in 50 ml of ethanol was stirred for 4 h at room temperature. The solvent was removed under reduced pressure, and the precipitate was filtered off, washed with water, and dried.

**7-[(Phenylsulfanyl)methyl]-7,8-dihydro[1,3]thiazolo[2,3-*i*]purine (IXa).** Yield 0.27 g (91%), mp 153–155°C. IR spectrum, ν, $cm^{-1}$: 1610, 1500, 1450, 1400, 1360, 1250, 1120, 1100, 890. $^1$H NMR spectrum, δ, ppm: 3.68–3.81 m (2H, $CH_2$), 3.87–3.90 m (1H, CH), 4.15–4.20 m (1H, CH), 5.65–5.70 m (1H, CH), 7.13 t (1H, $H_{arom}$, $J$ = 7.6 Hz), 7.22 t (2H, $H_{arom}$, $J$ = 7.6 Hz), 7.37 d (2H, $H_{arom}$, $J$ = 7.6 Hz), 8.61 s (1H, 2-H), 9.10 s (1H, 5-H). $^{13}$C NMR spectrum, $\delta_C$, ppm: 35.48 ($C^8$), 35.83 (7-$CH_2$), 66.87 ($C^7$), 126.46 ($C_{arom}$), 128.74 (2C, $C_{arom}$), 128.94 (3C, $C_{arom}$, $C^{9b}$), 133.42 ($C_{arom}$), 143.11 ($C^2$), 153.71 ($C^{9a}$), 156.09 ($C^5$), 156.56 ($C^{3a}$). Mass spectrum: $m/z$ 301 $[M + 1]^+$. Found, %: C 55.88; H 3.96; N 18.53; S 21.27. $C_{14}H_{12}N_4S_2$. Calculated, %: C 55.97; H 4.03; N 18.65; S 21.35. $M$ 300.40.

**7-[(4-Methylphenylsulfanyl)methyl]-7,8-dihydro-[1,3]thiazolo[2,3-*i*]purine (IXb).** Yield 0.27 g (86%), mp 119–121°C. IR spectrum, ν, $cm^{-1}$: 1610, 1500, 1440, 1410, 1350, 1260, 1170, 1120, 1100, 1080, 920, 890. $^1$H NMR spectrum, δ, ppm: 2.19 s (3H, $CH_3$), 3.61–3.78 m (2H, $CH_2$), 3.85–3.89 m (1H, CH), 4.13–4.18 m (1H, CH), 5.61–5.74 m (1H, CH), 7.00 d (2H, $H_{arom}$, $J$ = 7.6 Hz), 7.25 d (2H, $H_{arom}$, $J$ = 8.0 Hz), 8.60 s (1H, 2-H), 9.06 s (1H, 5-H). $^{13}$C NMR spectrum, $\delta_C$, ppm: 20.43 ($CH_3$), 35.47 ($C^8$), 36.57 (7-$CH_2$), 67.08 ($C^7$), 128.18 ($C^{9b}$), 129.40 (2C, $C_{arom}$), 129.60 (2C, $C_{arom}$), 129.61 ($C_{arom}$), 136.33 ($C_{arom}$), 143.26 ($C^2$), 154.00 ($C^{9a}$), 155.74 ($C^5$), 156.44 ($C^{3a}$). Mass spectrum: $m/z$ 315 $[M + 1]^+$. Found, %: C 57.23; H 4.46; N 17.75; S 20.29. $C_{15}H_{14}N_4S_2$. Calculated, %: C 57.30; H 4.49; N 17.82; S 20.40. $M$ 314.43.

**7-[(4-Nitrophenylsulfanyl)methyl]-7,8-dihydro-[1,3]thiazolo[2,3-*i*]purine (IXc).** Yield 0.34 g (97%), mp 241–243°C. IR spectrum, ν, $cm^{-1}$: 1630, 1500, 1450, 1400, 1330, 1260, 1180, 1090, 990. $^1$H NMR spectrum, δ, ppm: 3.85–3.93 m (3H, CH, $CH_2$), 4.17–4.22 m (1H, CH), 5.73–5.77 m (1H, CH), 7.60 d (2H, $H_{arom}$, $J$ = 8.4 Hz), 8.03 d (2H, $H_{arom}$, $J$ = 8.4 Hz), 8.56 s (1H, 2-H), 9.12 s (1H, 5-H). $^{13}$C NMR spectrum, $\delta_C$, ppm: 34.49 ($C^8$), 35.75 (7-$CH_2$), 66.42 ($C^7$), 123.64 (2C, $C_{arom}$), 127.56 (2C, $C_{arom}$), 128.49 ($C^{9b}$), 143.06 ($C^2$), 144.11 ($C_{arom}$), 144.99 ($C_{arom}$), 153.34 ($C^{9a}$), 156.74 ($C^5$), 157.08 ($C^{3a}$). Mass spectrum: $m/z$ 346 $[M + 1]^+$. Found, %: C 48.57; H 3.18; N 20.14; S 18.53. $C_{14}H_{11}N_5O_2S_2$. Calculated, %: C 48.68; H 3.21; N 20.28; S 18.57. $M$ 345.40.

**5-(4-Arylsulfanylmethyl-4,5-dihydro-1,3-thiazol-2-yl)-*N*-(morpholin-4-ylmethylidene)-1*H*-imidazol-4-amines Xa–Xc** were synthesized as described above for compound **VIb** from 1 mmol of **IXa–IXc** and 15 ml of morpholine.

***N*-(Morpholin-4-ylmethylidene)-5-(4-phenylsulfanylmethyl-4,5-dihydro-1,3-thiazol-2-yl)-1*H*-imidazol-4-amine (Xa).** Yield 0.29 g (75%), mp 159–161°C. IR spectrum, ν, $cm^{-1}$: 3220, 1620, 1580, 1440, 1370, 1290, 1230, 1180, 1120, 1070, 1020, 980, 930. $^1$H NMR spectrum, δ, ppm: 3.07–3.18 m (2H, $CH_2$), 3.33–3.51 m (4H, $CH_2$), 3.64 m (6H, $CH_2$), 4.54–4.69 m (1H, CH), 7.22 t (1H, $H_{arom}$, $J$ = 7.2 Hz), 7.35 t (2H, $H_{arom}$, $J$ = 7.2 Hz), 7.42 d (2H, $H_{arom}$, $J$ = 7.8 Hz), 7.48 s (1H, N=CH), 8.35 s (1H, 2-H), 12.34 s (1H, NH). $^{13}$C NMR spectrum, $\delta_C$, ppm: 36.17 ($C^{5'}$), 37.53 (4′-$CH_2$), 43.31 ($NCH_2$), 49.02 ($NCH_2$), 66.02 ($OCH_2$), 67.14 ($OCH_2$), 74.00 ($C^{4'}$), 113.03 ($C^4$), 126.31 ($C_{arom}$), 128.83 (2C, $C_{arom}$), 129.59 (2C, $C_{arom}$), 136.43 ($C_{arom}$), 136.68 ($C^2$), 151.59 ($C^5$), 152.48 (N=CH), 156.81 ($C^{2'}$). Found, %: C 55.67; H 5.42; N 18.03; S 16.42. $C_{18}H_{21}N_5OS_2$. Calculated, %: C 55.79; H 5.46; N 18.07; S 16.55.

**5-[4-(4-Methylphenylsulfanylmethyl)-4,5-dihydro-1,3-thiazol-2-yl]-*N*-(morpholin-4-ylmethylidene)-1*H*-imidazol-4-amine (Xb).** Yield 0.29 g (73%), mp 168–169°C. IR spectrum, ν, $cm^{-1}$: 3260, 2970, 2930, 1620, 1590, 1430, 1370, 1290, 1240, 1190, 1110, 1070, 1020, 980, 930. $^1$H NMR spectrum, δ, ppm: 2.28 s (3H, $CH_3$), 2.99–3.12 m (2H, $CH_2$), 3.25–3.44 m (4H, $CH_2$), 3.63 m (6H, $CH_2$), 4.52–4.59 m (1H, CH), 7.16 d (2H, $H_{arom}$, $J$ = 9.2 Hz), 7.31 d (2H, $H_{arom}$, $J$ = 7.6 Hz), 7.46 s (1H, N=CH), 8.35 s (1H, 2-H), 12.32 s (1H, NH). $^{13}$C NMR spectrum, $\delta_C$, ppm: 21.03 ($CH_3$), 36.04 ($C^{5'}$), 38.21 (4′-$CH_2$), 43.25 ($NCH_2$), 49.04 ($NCH_2$), 66.02 ($OCH_2$), 67.11 ($OCH_2$), 74.08 ($C^{4'}$), 113.06 ($C^4$), 129.61 (2C, $C_{arom}$), 130.24 (2C, $C_{arom}$), 132.84 ($C_{arom}$), 136.03 ($C_{arom}$), 136.35 ($C^2$), 151.62 ($C^5$), 152.42 (N=CH), 156.63 ($C^{2'}$). Mass spectrum: $m/z$ 402 $[M + 1]^+$. Found, %: C 56.71; H 5.67; N 17.38; S 15.84. $C_{19}H_{23}N_5OS_2$. Calculated, %: C 56.83; H 5.77; N 17.44; S 15.97. $M$ 401.55.

***N*-(Morpholin-4-ylmethylidene)-5-[4-(4-nitrophenylsulfanylmethyl)-4,5-dihydro-1,3-thiazol-2-yl]-1*H*-imidazol-4-amine (Xc).** Yield 0.34 g (79%),

mp 140–142°C. IR spectrum, ν, $cm^{-1}$: 1620, 1590, 1490, 1440, 1390, 1330, 1290, 1230, 1190, 1110, 1090, 1030, 940. $^1$H NMR spectrum, δ, ppm: 3.04–3.18 m (2H, $CH_2$), 3.31–3.48 m (4H, $CH_2$), 3.63 m (6H, $CH_2$), 4.70–4.79 m (1H, CH), 7.46 (1H, N=CH), 7.58 d (2H, $H_{arom}$, $J$ = 8.7 Hz), 8.13 d (2H, $H_{arom}$, $J$ = 8.7 Hz), 8.13 s (1H, 2-H), 12.23 s (1H, NH). $^{13}$C NMR spectrum, $\delta_C$, ppm: 36.07 ($C^{5'}$), 36.65 (4′-$CH_2$), 43.25 ($NCH_2$), 49.03 ($NCH_2$), 66.01 ($OCH_2$), 67.13 ($OCH_2$), 73.61 ($C^{4'}$), 112.96 ($C^4$), 124.35 (2C, $C_{arom}$), 126.97 (2C, $C_{arom}$), 136.28 ($C^2$), 144.93 ($C_{arom}$), 148.07 ($C_{arom}$), 151.64 ($C^5$), 152.52 (N=CH), 157.01 ($C^{2'}$). Found, %: C 49.83; H 4.61; N 19.36; S 14.75. $C_{18}H_{20}N_6O_3S_2$. Calculated, %: C 49.99; H 4.66; N 19.43; S 14.83.

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