ISSN 1070-4280, Russian Journal of Organic Chemistry, 2016, Vol. 52, No. 6, pp. 873–878. © Pleiades Publishing, Ltd., 2016.
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Polyfunctional Imidazoles: XII.[1] Synthesis of 1-[(4-Chloro-1*H*-imidazol-5-yl)methyl]-Substituted 1,2,3-Triazoles and Dihydropyrrolo[3,4-*d*]triazoles from 5-(Azidomethyl)-4-chloro-1*H*-imidazoles

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Received January 11, 2016

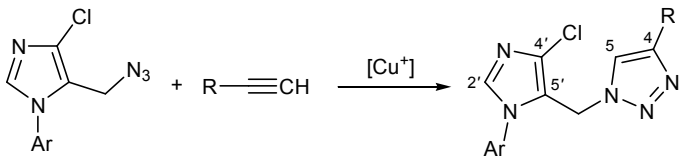
Abstract—1-Aryl-5-(azidomethyl)-4-chloro-1*H*-imidazoles reacted with terminal acetylenes in the presence of copper catalyst to give 1-[(1-aryl-4-chloro-1*H*-imidazol-5-yl)methyl]-1*H*-1,2,3-triazoles, and their reactions with *N*-arylmaleimides on heating in benzene afforded 5-aryl-1-[(1-aryl-4-chloro-1*H*-imidazol-5-yl)methyl]-3a,6a-dihydropyrrolo[3,4-*d*][1,2,3]triazole-4,6(1*H*,5*H*)-diones.

DOI: 10.1134/S107042801606018X

5-(Azidomethyl)imidazoles constitute a synthetically attractive group of functionalized imidazoles that are widely used for the preparation of the corresponding 5-(aminomethyl) derivatives. The latter are important intermediate products in the synthesis of nonpeptide angiotensine II receptor antagonists [2, 3] and inhibitors of thrombin and trypsin [4], lipoprotein-associated phospholipase [5], and prenyl-protein transferase [6, 7]. However, the synthetic potential of the azido group in 5-(azidomethyl)imidazoles as one of the most effective 1,3-dipoles in a modular approach to triazole-conjugated heterocyclic systems remains unexplored. In recent time, 1,2,3-triazole compounds have acquired particular importance for biomedical studies [8–13]. Copper-catalyzed [3+2]-cycloaddition of azides to terminal alkynes, which may be regarded as "click" reaction, is among the most powerful methods for the synthesis of 1,2,3-triazoles [14–16]. Cycloaddition of azides to activated alkenes, in particular to maleimides, also deserves attention; this reaction was successfully used to synthesize alkaloids [17, 18]. The reaction of 5-(azidomethyl)-1,2,4-oxadiazoles with maleimides, leading to dihydropyrrolo[3,4-*d*][1,2,3]triazoles which showed antitumor [19] and antiprotozoa activity [20], seems to be very interesting as well.

In the present work we studied reactions of 5-(azidomethyl)-4-chloroimidazoles **1a**–**1c** [21] with terminal acetylenes and *N*-arylmaleimides with the goal of obtaining flexible hybrid structures consisting

Scheme 1.



1a–1c **2a–2c** **3a–3h**

1, Ar = 4-FC_6H_4 (**a**), 4-ClC_6H_4 (**b**), 4-MeC_6H_4 (**c**); **2**, R = Ph (**a**), COOMe (**b**), $HOCH_2$ (**c**); **3**, R = Ph, Ar = 4-FC_6H_4 (**a**), 4-ClC_6H_4 (**b**), 4-MeC_6H_4 (**c**); R = COOMe, Ar = 4-FC_6H_4 (**d**), 4-ClC_6H_4 (**e**), 4-MeC_6H_4 (**f**); R = $HOCH_2$, Ar = 4-ClC_6H_4 (**g**), 4-MeC_6H_4 (**h**).

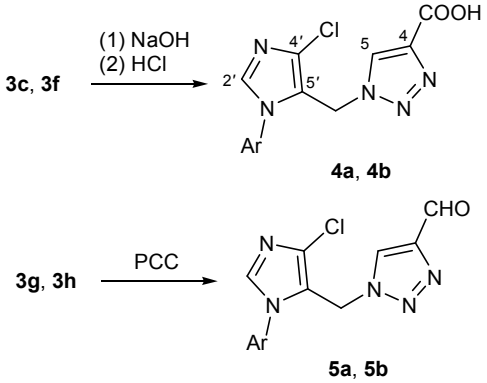
[1] For communication XI, see [1].

of imidazole and 1,2,3-triazole or pyrrolotriazole rings as promising substrates for further chemical transformations and biological screening. Azidomethyl derivatives **1a**–**1c** smoothly reacted with phenylacetylene (**2a**) and methyl propynoate (**2b**) in aqueous tetrahydrofuran in the presence of copper(II) sulfate–ascorbic acid as a source of copper(I) ions to give 4-substituted 1-(imidazol-5-ylmethyl)-1*H*-1,2,3-triazoles **3a**–**3f** in 80–85% yield (Scheme 1). However, these conditions were inappropriate for the reaction of imidazoles **1** with propargyl alcohol (**2c**). We succeeded in isolating the corresponding cycloadducts **3g** and **3h** in 72–75% yield using *tert*-butyl alcohol as solvent and copper(II) acetate as catalyst [22].

The formation of triazole ring in the above [3+2]-cycloaddition reactions was confirmed by the ^{1}H NMR spectra of compounds **3**, which contained a signal of 5-H at δ 8.21–8.25 (**3a**–**3c**), 8.44–8.47 (**3d**–**3f**), or 7.61–7.68 ppm (**3g**, **3h**). In the ^{13}C NMR spectra of **3a**–**3h**, the C^4 and C^5 signals of the triazole ring were observed at δ_C 138–148 and 122–128 ppm, respectively.

Compounds **3e** and **3f** containing an ester moiety were hydrolyzed with aqueous sodium hydroxide, and subsequent acidification gave carboxylic acids **4a** and **4b**. Hydroxymethyl derivatives **3g** and **3h** were oxidized with pyridinium chlorochromate [23] to aldehydes **5a** and **5b** (Scheme 2). Compounds **4a**, **4b**, **5a**, and **5b** are promising building blocks for combinatorial chemistry.

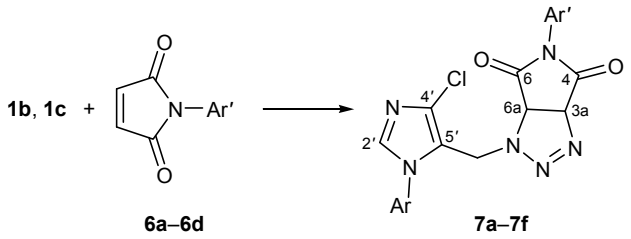
Scheme 2.



4, **5**, Ar = 4-ClC_6H_4 (**a**), 4-MeC_6H_4 (**b**).

According to the data of [20], reactions of 3-aryl-5-(azidomethyl)-1,2,4-oxadiazoles with *N*-phenylmaleimide in boiling benzene required 2–4 days. In contrast, the cycloaddition of imidazolylmethyl azides **1b** and **1c** with *N*-arylmaleimides **6a**–**6d** in benzene under reflux was complete in 2 h, yielding 72–81% of 1-(imidazol-5-ylmethyl)-3a,6a-dihydropyrrolo[3,4-*d*]-[1,2,3]triazole-4,6(1*H*,5*H*)-diones **7a**–**7f** (Scheme 3).

Scheme 3.



6, Ar′ = Ph (**a**), 4-ClC_6H_4 (**b**), 4-BrC_6H_4 (**c**), 4-MeC_6H_4 (**d**); **7**, Ar = Ar′ = 4-ClC_6H_4 (**a**); Ar = 4-ClC_6H_4, Ar′ = 4-BrC_6H_4 (**b**), 4-MeC_6H_4 (**c**); Ar = 4-MeC_6H_4, Ar′ = Ph (**d**), 4-ClC_6H_4 (**e**); Ar = Ar′ = 4-MeC_6H_4 (**f**).

The structure of **7a**–**7f** was confirmed by spectral data. In particular, they showed in the IR spectra strong carbonyl stretching bands in the region 1713–1716 cm^{-1}. In the ^{1}H NMR spectra of **7a**–**7f**, the 6a-H and 3a-H protons of the dihydropyrrolotriazole fragment resonated as doublets at δ 4.23–4.27 and 5.62–5.68 ppm, respectively with a coupling constant ^3J of 10.8 Hz, indicating *cis* junction of the pyrrole and triazole rings. Protons of the bridging methylene groups gave rise to two doublets at δ 4.88–4.91 and 4.94–5.01 ppm (*AB*, ^2J = 15.2–16.0 Hz). The C^{6a} and C^{3a} signals of **7a**–**7f** were located in the ^{13}C NMR spectra at δ_C 58–59 and 82–83 ppm, respectively.

EXPERIMENTAL

The IR spectra were recorded in KBr on a UR-20 spectrometer. The ^{1}H and ^{13}C NMR spectra were measured on a Bruker Avance DRX-500 spectrometer at 500.13 and 127.75 MHz, respectively, using DMSO-d_6 as solvent and tetramethylsilane as internal standard. The mass spectra (electron impact, 70 eV) were obtained on an Agilent instrument.

Azidomethyl derivative **1b** was synthesized by us previously from the corresponding 5-(chloromethyl)-imidazole and sodium azide in anhydrous DMF [21]. Compounds **1a** and **1c** were prepared in a similar way.

5-(Azidomethyl)-4-chloro-1-(4-fluorophenyl)-1*H*-imidazole (1a). Yield 87%, mp 100–102°C. IR spectrum: ν 2140 cm^{-1} (N_3). ^{1}H NMR spectrum, δ, ppm: 4.43 s (2H, CH_2), 7.42–7.61 m (4H, H_{arom}), 7.99 s (1H, 2-H). Found, %: C 47.99; H 2.70; N 27.74. *m*/*z* 252 $[M + 1]^+$. $C_{10}H_7ClFN_5$. Calculated, %: C 47.73; H 2.80; N 27.83. *M* 251.65.

5-(Azidomethyl)-4-chloro-1-(4-methylphenyl)-1*H*-imidazole (1c). Yield 85%, mp 95–97°C. IR spectrum: ν 2140 cm^{-1} (N_3). ^1H NMR spectrum, δ, ppm: 2.38 s (3H, CH_3), 4.41 s (2H, CH_2), 7.39 s (4H, H_{arom}), 7.99 s (1H, 2-H). Found, %: C 53.59; H 4.15; N 28.40. *m*/*z* 248[*M* + 1]$^+$. $C_{11}H_{10}ClN_5$. Calculated, %: C 53.34; H 4.07; N 28.27. *M* 247.69.

Compounds 3a–3f (*general procedure*). Azide **1a**–**1c**, 10 mmol, was dissolved in 10 mL of tetrahydrofuran, and 1 g (10 mmol) of phenylacetylene (in the synthesis of **3a**–**3c**) or 0.84 g (10 mmol) of methyl propynoate (in the synthesis of **3d**–**3f**), 0.25 g (1 mmol) of copper(II) sulfate pentahydrate, and 0.35 g (2 mmol) of ascorbic acid were added. The resulting solution was diluted with water until an emulsion was formed, 2–3 drops of triethylamine were added, and the mixture was stirred for 12 h at room temperature and poured into 20 mL of water. The precipitate was filtered off, washed with water, dried, and recrystallized from 80% ethanol.

1-{[4-Chloro-1-(4-fluorophenyl)-1*H*-imidazol-5-yl]methyl}-4-phenyl-1*H*-1,2,3-triazole (3a). Yield 79%, mp 168–170°C. ^1H NMR spectrum, δ, ppm: 5.63 s (2H, CH_2), 7.31–7.55 m (7H, H_{arom}), 7.76 d (2H, H_{arom}, *J* = 7.2 Hz), 7.99 s (1H, 2′-H), 8.25 s (1H, 5-H). ^{13}C NMR spectrum, δ_C, ppm: 41.75 (CH_2), 116.50 d (C_{arom}, $^2J_{CF}$ = 23.8 Hz), 120.28 ($C^{5'}$), 128.93 (C^5), 132.64 ($C^{4'}$), 137.64 ($C^{2'}$), 146.61 (C^4), 121.14, 128.39 d (C_{arom}, $^3J_{CF}$ = 8.5 Hz), 129.84, 130.38, 131.28, 137.64 (C_{arom}), 162.01 d (C_{arom}, $^1J_{CF}$ = 248.5 Hz). Found, %: C 60.95; H 3.79; N 19.97. *m*/*z* 354 [*M* + 1]$^+$. $C_{18}H_{13}ClFN_5$. Calculated, %: C 61.11; H 3.70; N 19.80. *M* 353.79.

1-{[4-Chloro-1-(4-chlorophenyl)-1*H*-imidazol-5-yl]methyl}-4-phenyl-1*H*-1,2,3-triazole (3b). Yield 77%, mp 180–182°C. ^1H NMR spectrum, δ, ppm: 5.61 s (2H, CH_2), 7.31–7.62 m (7H, H_{arom}), 7.76 d (2H, H_{arom}, *J* = 7.2 Hz), 8.01 s (1H, 2′-H), 8.27 s (1H, 5-H). ^{13}C NMR spectrum, δ_C, ppm: 41.72 (CH_2), 120.79 ($C^{5'}$), 127.88 (C^5), 133.93 ($C^{4'}$), 137.43 ($C^{2'}$), 146.21 (C^4), 121.13, 125.26, 127.91, 128.91, 129.74 130.06, 130.36, 133.86 (C_{arom}). Found, %: C 58.18; H 3.43; N 19.05. *m*/*z* 371 [*M* + 1]$^+$. $C_{18}H_{13}Cl_2N_5$. Calculated, %: C 58.39; H 3.54; N 18.92. *M* 370.24.

1-{[4-Chloro-1-(4-methylphenyl)-1*H*-imidazol-5-yl]methyl}-4-phenyl-1*H*-1,2,3-triazole (3c). Yield 75%, mp 185–187°C. ^1H NMR spectrum, δ, ppm: 2.34 s (3H, CH_3), 5.58 s (2H, CH_2), 7.30–7.44 m (7H, H_{arom}), 7.76 d (2H, H_{arom}, *J* = 7.4 Hz), 7.96 s (1H, 2′-H), 8.21 s (1H, 5-H). ^{13}C NMR spectrum, δ_C, ppm: 20.36 (CH_3), 41.79 (CH_2), 120.72 ($C^{5'}$), 137.50 ($C^{2'}$), 127.75 (C^5), 132.42 ($C^{4'}$), 146.15 (C^4), 121.04, 125.75, 128.80, 129.84, 129.94 130.37, 132.42, 138.95 (C_{arom}). Found, %: C 65.45; H 4.73; N 19.93. *m*/*z* 350 [*M* + 1]$^+$. $C_{19}H_{16}ClN_5$. Calculated, %: C 65.24; H 4.61; N 20.02. *M* 349.83.

Methyl 1-{[4-chloro-1-(4-fluorophenyl)-1*H*-imidazol-5-yl]methyl}-1*H*-1,2,3-triazole-4-carboxylate (3d). Yield 80%, mp 141–142°C. IR spectrum: ν 1725 cm^{-1} (C=O). ^1H NMR spectrum, δ, ppm: 3.79 s (3H, CH_3), 5.62 s (2H, CH_2), 7.32–7.49 m (4H, H_{arom}), 8.03 s (1H, 2′-H), 8.44 s (1H, 5-H). ^{13}C NMR spectrum, δ_C, ppm: 41.94 (CH_2), 51.62 (CH_3O), 116.38 d (C_{arom}, $^2J_{CF}$ = 20.1 Hz), 120.53 ($C^{5'}$), 128.80 (C^5), 132.19 ($C^{4'}$), 137.42 ($C^{2'}$), 138.25 (C^4), 128.30 d (C_{arom}, $^3J_{CF}$ = 8.8 Hz), 129.77 (C_{arom}), 160.25 (C=O), 161.92 (C_{arom}, $^1J_{CF}$ = 245.0 Hz). Found, %: C 49.84; H 3.19; N 20.75. *m*/*z* 336 [*M* + 1]$^+$. $C_{14}H_{11}ClFN_5O_2$. Calculated, %: C 50.09; H 3.30; N 20.86. *M* 335.73.

Methyl 1-{[4-chloro-1-(4-chlorophenyl)-1*H*-imidazol-5-yl]methyl}-1*H*-1,2,3-triazole-4-carboxylate (3e). Yield 80%, mp 156–158°C. IR spectrum: ν 1730 cm^{-1} (C=O). ^1H NMR spectrum, δ, ppm: 3.79 s (3H, CH_3), 5.64 s (2H, CH_2), 7.44 d (2H, H_{arom}, *J* = 8.4 Hz), 7.59 d (2H, H_{arom}, *J* = 8.4 Hz), 8.02 s (1H, 2′-H), 8.47 s (1H, 5-H). ^{13}C NMR spectrum, δ_C, ppm: 41.92 (CH_2), 51.39 (CH_3O), 120.82 ($C^{5'}$), 128.90 (C^5), 133.88 ($C^{4'}$), 138.07 ($C^{2'}$), 138.17 (C^4), 127.68, 129.50, 129.90, 133.61 (C_{arom}), 160.25 (C=O). Found, %: C 47.92; H 3.20; N 19.78. *m*/*z* 353 [*M* + 1]$^+$. $C_{14}H_{11}Cl_2N_5O_2$. Calculated, %: C 47.75; H 3.15; N 19.89. *M* 352.18.

Methyl 1-{[4-chloro-1-(4-methylphenyl)-1*H*-imidazol-5-yl]methyl}-1*H*-1,2,3-triazole-4-carboxylate (3f). Yield 80%, mp 139–140°C. IR spectrum: ν 1725 cm^{-1} (C=O). ^1H NMR spectrum, δ, ppm: 2.36 s (3H, CH_3), 3.79 s (3H, CH_3), 5.61 s (2H, CH_2), 7.26 d (2H, H_{arom}, *J* = 7.6 Hz), 7.31 d (2H, H_{arom}, *J* = 7.6 Hz), 7.93 s (1H, 2′-H), 8.38 s (1H, 5-H). ^{13}C NMR spectrum, δ_C, ppm: 20.72 (CH_3), 42.03 (CH_2), 51.67 (CH_3O), 120.40 ($C^{5'}$), 128.85 (C^5), 132.30 ($C^{4'}$), 137.22 ($C^{2'}$), 138.25 (C^4), 125.53, 129.82, 129.94, 139.06 (C_{arom}), 160.40 (C=O). Found, %: C 54.52; H 4.14; N 20.98. *m*/*z* 332 [*M* + 1]$^+$. $C_{15}H_{14}ClN_5O_2$. Calculated, %: C 54.31; H 4.25; N 21.11. *M* 331.76.

Compounds 3g and 3h (*general procedure*). A 5% aqueous solution of copper(II) acetate, 1 mL, was added under argon to a mixture of 10 mmol of azide **1b** or **1c**, 0.84 g (15 mmol) of propargyl alcohol (**2c**), and 5 mL of *tert*-butyl alcohol. The mixture was

stirred for 18 h at room temperature, 10 mL of methylene chloride and 10 mL of water were added, and the organic layer was separated, dried over sodium sulfate, and evaporated. The residue was purified by silica gel column chromatography using hexane–ethyl acetate (3:2) as eluent.

(1-{[4-Chloro-1-(4-chlorophenyl)-1*H*-imidazol-5-yl]methyl}-1*H*-1,2,3-triazol-4-yl)methanol (3g). Yield 72%, mp 121–122°C. IR spectrum: ν 3345 cm^{-1} (OH). ^{1}H NMR spectrum, δ, ppm: 4.42 d (2H, C**H**$_2$OH, J = 5.6 Hz), 5.13 t (1H, OH, J = 5.6 Hz), 5.53 s (2H, CH_2), 7.45 d (2H, H_{arom}, J = 8.4 Hz), 7.61 d (2H, H_{arom}, J = 8.4 Hz), 7.68 s (1H, 5-H), 7.99 s (1H, 2′-H). ^{13}C NMR spectrum, δ_C, ppm: 41.30 (CH_2), 54.86 (CH_2), 121.13 ($C^{5'}$), 122.45 (C^5), 133.81 ($C^{4'}$), 137.57 ($C^{2'}$), 148.13 (C^4), 127.71, 129.63, 130.03, 133.97 (C_{arom}). Found, %: C 48.35; H 3.33; N 21.70. *m*/*z* 325 $[M + 1]^+$. $C_{13}H_{11}Cl_2N_5O$. Calculated, %: C 48.17; H 3.42; N 21.60. *M* 324.17.

(1-{[4-Chloro-1-(4-methylphenyl)-1*H*-imidazol-5-yl]methyl}-1*H*-1,2,3-triazol-4-yl)methanol (3h). Yield 75%, mp 129–130°C. IR spectrum: ν 3345 cm^{-1} (OH). ^{1}H NMR spectrum, δ, ppm: 2.37 s (3H, CH_3), 4.42 d (2H, C**H**$_2$OH, J = 5.6 Hz), 5.11 t (1H, OH, J = 5.6 Hz), 5.49 s (2H, CH_2), 7.25 d (2H, H_{arom}, J = 8.0 Hz), 7.33 d (2H, H_{arom}, J = 8.0 Hz), 7.61 s (1H, 5-H), 7.93 s (1H, 2′-H). ^{13}C NMR spectrum, δ_C, ppm: 20.73 (CH_3), 41.46 (CH_2), 54.97 (CH_2), 121.10 ($C^{5'}$), 124.44 (C^5), 132.53 ($C^{4'}$), 137.64 ($C^{2'}$), 148.24 (C^4), 125.80, 129.93, 130.24, 139.12 (C_{arom}). Found, %: C 55.65; H 4.53; N 23.20. *m*/*z* 304 $[M + 1]^+$. $C_{14}H_{14}ClN_5O$. Calculated, %: C 55.36; H 4.65; N 23.06. *M* 303.75.

Compounds 4a and 4b (*general procedure*). Sodium hydroxide, 0.04 g (10 mmol), was added to a solution of 5 mmol of ester **3e** or **3f** in 10 mL of ethanol, and the mixture was stirred for 1 h at room temperature. The mixture was filtered, the filtrate was acidified with 10% aqueous HCl to pH 5, and the precipitate was filtered off, dried, and recrystallized from 80% ethanol.

1-{[4-Chloro-1-(4-chlorophenyl)-1*H*-imidazol-5-yl]methyl}-1*H*-1,2,3-triazole-4-carboxylic acid (4a). Yield 78%, mp 139–140°C. IR spectrum, ν, cm^{-1}: 2870–2520 (COOH), 1705 (C=O). ^{1}H NMR spectrum, δ, ppm: 5.63 s (2H, CH_2), 7.45 d (2H, H_{arom}, J = 8.4 Hz), 7.59 d (2H, H_{arom}, J = 8.4 Hz), 7.98 s (1H, 2′-H), 8.35 s (1H, 5-H), 13.09 br.s (1H, COOH). ^{13}C NMR spectrum, δ_C, ppm: 41.82 (CH_2), 120.61 ($C^{5'}$), 128.75 (C^5), 133.72 ($C^{4'}$), 137.73 ($C^{2'}$), 139.42 (C^4), 127.86, 129.69, 130.06, 137.73 (C_{arom}), 161.36 (C=O). Found, %: C 46.32; H 2.60; N 20.85. *m*/*z* 339 $[M + 1]^+$. $C_{13}H_9Cl_2N_5O_2$. Calculated, %: C 46.18; H 2.68; N 20.71. *M* 338.15.

1-{[4-Chloro-1-(4-methylphenyl)-1*H*-imidazol-5-yl]methyl}-1*H*-1,2,3-triazole-4-carboxylic acid (4b). Yield 78%, mp 133–134°C. IR spectrum, ν, cm^{-1}: 2850–2510 (COOH), 1710 (C=O). ^{1}H NMR spectrum, δ, ppm: 2.36 s (3H, CH_3), 5.99 s (2H, CH_2), 7.27 d (2H, H_{arom}, J = 7.2 Hz), 7.32 d (2H, H_{arom}, J = 7.2 Hz), 7.92 s (1H, 2′-H), 8.26 s (1H, 5-H), 13.07 br.s (1H, COOH). ^{13}C NMR spectrum, δ_C, ppm: 21.39 (CH_3), 41.57 (CH_2), 120.55 ($C^{5'}$), 128.48 (C^5), 132.36 ($C^{4'}$), 137.50 ($C^{2'}$), 139.11 (C^4), 125.51, 129.84, 130.05, 139.41 (C_{arom}), 161.40 (C=O). Found, %: C 53.12; H 3.90; N 21.88. *m*/*z* 318 $[M + 1]^+$. $C_{14}H_{12}ClN_5O_2$. Calculated, %: C 52.92; H 3.81; N 22.04. *M* 317.74.

Compounds 5a and 5b (*general procedure*). A solution of 5 mmol of alcohol **3g** or **3h** in 10 mL of methylene chloride was added to a suspension of 1.56 g (7.5 mmol) of pyridinium chlorochromate in 10 mL of methylene chloride, and the mixture was stirred for 1 h at room temperature. The mixture was poured into 20 mL of water, the precipitate was filtered off, the organic layer was separated and dried over sodium sulfate, the solvent was removed under reduced pressure, and the residue was purified by silica gel column chromatography using hexane–ethyl acetate (4:1) as eluent.

1-{[4-Chloro-1-(4-chlorophenyl)-1*H*-imidazol-5-yl]methyl}-1*H*-1,2,3-triazole-4-carbaldehyde (5a). Yield 52%, mp 141–142°C. IR spectrum: ν 1710 cm^{-1} (C=O). ^{1}H NMR spectrum, δ, ppm: 5.63 s (2H, CH_2), 7.47 d (2H, H_{arom}, J = 8.4 Hz), 7.60 d (2H, H_{arom}, J = 8.4 Hz), 8.00 s (1H, 2′-H), 8.62 s (1H, 5-H), 9.93 s (1H, CHO). ^{13}C NMR spectrum, δ_C, ppm: 42.07 (CH_2), 120.40 ($C^{5'}$), 128.25 (C^5), 133.67 ($C^{4'}$), 137.81 ($C^{2'}$), 146.52 (C^4), 127.71, 129.71, 130.22, 134.05 (C_{arom}), 184.71 (CHO). Found, %: C 48.22; H 2.75; N 21.85. *m*/*z* 323 $[M + 1]^+$. $C_{13}H_9Cl_2N_5O$. Calculated, %: C 48.47; H 2.82; N 21.74. *M* 322.16.

1-{[4-Chloro-1-(4-methylphenyl)-1*H*-imidazol-5-yl]methyl}-1*H*-1,2,3-triazole-4-carbaldehyde (5b). Yield 55%, mp 91–92°C. IR spectrum: ν 1705 cm^{-1} (C=O). ^{1}H NMR spectrum, δ, ppm: 2.36 s (3H, CH_3), 7.28 d (2H, H_{arom}, J = 8.0 Hz), 7.34 d (2H, H_{arom}, J = 8.0 Hz), 7.94 s (1H, 2′-H), 8.52 s (1H, 5-H), 9.93 s (1H, CHO). ^{13}C NMR spectrum, δ_C, ppm: 20.51 (CH_3), 42.13 (CH_2), 120.32 ($C^{5'}$), 127.92 (C^5), 132.31 ($C^{4'}$), 137.44 ($C^{2'}$), 146.49 (C^4), 126.05, 129.95, 130.10,

139.10 (C_{arom}). Found, %: C 55.52; H 3.90; N 23.08. *m*/*z* 302 $[M + 1]^+$. $C_{14}H_{12}ClN_5O$. Calculated, %: C 55.73; H 4.01; N 23.21. *M* 301.74.

Compounds 7a–7f (*general procedure*). Azide **1a**–**1c**, 10 mmol, was dissolved in 10 mL of anhydrous benzene, 10 mmol of *N*-arylmaleinimide **6a**–**6d** was added, and the mixture was refluxed for 2 h. The solvent was removed under reduced pressure, and the residue was purified by silica gel column chromatography using hexane–ethyl acetate (4:1) as eluent.

1-{[4-Chloro-1-(4-chlorophenyl)-1*H*-imidazol-5-yl]methyl}-5-(4-chlorophenyl)-3a,6a-dihydropyrrolo[3,4-*d*][1,2,3]triazole-4,6(1*H*,5*H*)-dione (7a). Yield 72%, mp >250°C. IR spectrum: ν 1715 cm^{-1} (C=O). ^{1}H NMR spectrum, δ, ppm: 4.27 d (1H, *J* = 10.8 Hz), 4.91 d (1H, *J* = 15.6 Hz), 4.99 d (1H, *J* = 15.6 Hz), 5.65 d (1H, *J* = 10.8 Hz), 7.17 d (2H, H_{arom}, *J* = 8.4 Hz), 7.47 d (2H, H_{arom}, *J* = 8.4 Hz), 7.53–7.59 m (4H, H_{arom}), 7.93 s (1H, 2′-H). ^{13}C NMR spectrum, δ_C, ppm: 41.62 (CH_2), 58.69 (CH), 82.57 (CH), 121.61 ($C^{5'}$), 133.27 ($C^{4'}$), 137.14 ($C^{2'}$), 127.57, 128.38, 128.99, 129.41, 129.87, 130.22, 133.72, 134.24 (C_{arom}), 169.81 (C=O), 170.97 (C=O). Found, %: C 50.23; H 2.80; N 17.50. *m*/*z* 476 $[M + 1]^+$. $C_{20}H_{13}Cl_3N_6O_2$. Calculated, %: C 50.50; H 2.75; N 17.67. *M* 475.72.

5-(4-Bromophenyl)-1-{[4-chloro-1-(4-chlorophenyl)-1*H*-imidazol-5-yl]methyl}-3a,6a-dihydropyrrolo[3,4-*d*][1,2,3]triazole-4,6(1*H*,5*H*)-dione (7b). Yield 78%, mp >250°C. IR spectrum: ν 1715 cm^{-1} (C=O). ^{1}H NMR spectrum, δ, ppm: 4.27 d (1H, *J* = 10.8 Hz), 4.90 d (1H, *J* = 15.2 Hz), 4.99 d (1H, *J* = 15.2 Hz), 5.65 d (1H, *J* = 10.8 Hz), 7.11 d (2H, H_{arom}, *J* = 7.6 Hz), 7.47 d (2H, H_{arom}, *J* = 7.8 Hz), 7.58 d (2H, H_{arom}, *J* = 7.8 Hz), 7.71 d (2H, H_{arom}, *J* = 7.6 Hz), 7.92 s (1H, 2′-H). ^{13}C NMR spectrum, δ_C, ppm: 41.62 (CH_2), 58.73 (CH), 82.89 (CH), 121.05 ($C^{5'}$), 133.72 ($C^{4'}$), 137.12 ($C^{2'}$), 121.77, 127.77, 128.69, 129.47, 129.87, 130.66, 132.01, 134.23 (C_{arom}), 169.76 (C=O), 170.92 (C=O). Found, %: C 45.99; H 2.61; N 16.28. *m*/*z* 521 $[M + 1]^+$. $C_{20}H_{13}BrCl_2N_6O_2$. Calculated, %: C 46.18; H 2.52; N 16.16. *M* 520.18.

1-{[4-Chloro-1-(4-chlorophenyl)-1*H*-imidazol-5-yl]methyl}-5-(4-methylphenyl)-3a,6a-dihydropyrrolo[3,4-*d*][1,2,3]triazole-4,6(1*H*,5*H*)-dione (7c). Yield 75%, mp 202–204°C. IR spectrum: ν 1715 cm^{-1} (C=O). ^{1}H NMR spectrum, δ, ppm: 2.33 s (3H, CH_3), 7.23 d (1H, *J* = 10.8 Hz), 4.90 d (1H, *J* = 15.6 Hz), 5.01 d (1H, *J* = 15.6 Hz), 5.64 d (1H, *J* = 10.8 Hz), 6.98 d (2H, H_{arom}, *J* = 7.6 Hz), 7.29 d (2H, H_{arom}, *J* = 7.6 Hz), 7.47 d (2H, H_{arom}, *J* = 8.0 Hz), 7.57 d (2H, H_{arom}, *J* = 8.0 Hz), 7.93 s (1H, 2′-H). ^{13}C NMR spectrum, δ_C, ppm: 20.44 (CH_3), 41.68 (CH_2), 58.66 (CH), 82.94 (CH), 121.04 ($C^{5'}$), 133.70 ($C^{4'}$), 137.13 ($C^{2'}$), 126.33, 127.43, 128.75, 129.48, 129.59, 129.87, 134.25, 138.35 (C_{arom}), 170.09 (C=O), 171.29 (C=O). Found, %: C 55.52; H 3.43; N 18.58. *m*/*z* 456 $[M + 1]^+$. $C_{21}H_{16}Cl_2N_6O_2$. Calculated, %: C 55.40; H 3.54; N 18.46. *M* 455.31.

1-{[4-Chloro-1-(4-methylphenyl)-1*H*-imidazol-5-yl]methyl}-5-phenyl-3a,6a-dihydropyrrolo[3,4-*d*][1,2,3]triazole-4,6(1*H*,5*H*)-dione (7d). Yield 81%, mp 232–234°C. IR spectrum: ν 1710 cm^{-1} (C=O). ^{1}H NMR spectrum, δ, ppm: 2.33 s (3H, CH_3), 4.27 d (1H, *J* = 10.8 Hz), 4.88 d (1H, *J* = 15.6 Hz), 4.94 d (1H, *J* = 15.6 Hz), 5.64 d (1H, *J* = 10.8 Hz), 7.12 d (2H, H_{arom}, *J* = 7.6 Hz), 7.44 s (4H, H_{arom}), 7.42–7.53 m (3H, H_{arom}), 7.86 s (1H, 2′-H). ^{13}C NMR spectrum, δ_C, ppm: 20.74 (CH_3), 41.83 (CH_2), 59.28 (CH), 83.16 (CH), 121.13 ($C^{5'}$), 132.99 ($C^{4'}$), 137.28 ($C^{2'}$), 125.65, 126.84, 128.84, 129.16, 129.67, 130.11, 131.54, 138.81 (C_{arom}), 170.18 (C=O), 171.27 (C=O). Found, %: C 47.92; H 3.20; N 19.78. *m*/*z* 421 $[M + 1]^+$. $C_{21}H_{17}ClN_6O_2$. Calculated, %: C 47.75; H 3.15; N 19.89. *M* 420.86.

1-{[4-Chloro-1-(4-methylphenyl)-1*H*-imidazol-5-yl]methyl}-5-(4-chlorophenyl)-3a,6a-dihydropyrrolo[3,4-*d*][1,2,3]triazole-4,6(1*H*,5*H*)-dione (7e). Yield 74%, mp 248–250°C. IR spectrum: ν 1715 cm^{-1} (C=O). ^{1}H NMR spectrum, δ, ppm: 2.33 s (3H, CH_3), 4.25 d (1H, *J* = 10.8 Hz), 4.88 d (1H, *J* = 16.0 Hz), 4.98 d (1H, *J* = 16.0 Hz), 5.64 d (1H, *J* = 10.8 Hz), 7.17 d (2H, H_{arom}, *J* = 8.0 Hz), 7.30 s (4H, H_{arom}), 7.58 d ($2H_{arom}$, *J* = 8.0 Hz), 7.86 s (1H, 2′-H). ^{13}C NMR spectrum, δ_C, ppm: 20.73 (CH_3), 41.64 (CH_2), 58.77 (CH), 82.84 (CH), 121.00 ($C^{5'}$), 133.25 ($C^{4'}$), 136.90 ($C^{2'}$), 125.58, 128.44, 129.08, 129.52, 129.94, 130.25, 132.86, 138.68 (C_{arom}), 169.85 (C=O), 170.54 (C=O). Found, %: C 55.52; H 3.44; N 18.58. *m*/*z* 456 $[M + 1]^+$. $C_{21}H_{16}Cl_2N_6O_2$. Calculated, %: C 55.40; H 3.54; N 18.46. *M* 455.31.

1-{[4-Chloro-1-(4-methylphenyl)-1*H*-imidazol-5-yl]methyl}-5-(4-methylphenyl)-3a,6a-dihydropyrrolo[3,4-*d*][1,2,3]triazole-4,6(1*H*,5*H*)-dione (7f). Yield 72%, mp 218–220°C. IR spectrum: ν 1715 cm^{-1} (C=O). ^{1}H NMR spectrum, δ, ppm: 2.33 s (6H, CH_3), 4.23 d (1H, *J* = 10.8 Hz), 4.87 d (1H, *J* = 15.6 Hz), 4.97 d (1H, *J* = 15.6 Hz), 5.62 d (1H, *J* = 10.8 Hz), 6.98 d (2H, H_{arom}, *J* = 8.0 Hz), 7.26–7.31 m (6H, H_{arom}), 7.85 s (1H, 2′-H). ^{13}C NMR spectrum, δ_C, ppm:

20.48 (CH_3), 41.71 (CH_2), 58.91 (CH), 82.45 (CH), 120.99 ($C^{5'}$), 132.87 ($C^{4'}$), 136.97 ($C^{2'}$), 125.36, 126.56, 128.78, 129.52, 129.72, 133.41, 138.33, 138.67 (C_{arom}), 170.12 (C=O), 171.23 (C=O). Found, %: C 60.95; H 4.32; N 19.45. *m*/*z* 435 $[M + 1]^+$. $C_{22}H_{19}ClN_6O_2$. Calculated, %: C 60.76; H 4.40; N 19.32. *M* 434.89.

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