2-(Azidomethyl)phenylboronic acid in the synthesis of isoquinoline derivatives

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2-(Azidomethyl)phenyllead triacetate was obtained by the reaction of 2-(azidomethyl)phenylboronic acid with lead tetraacetate. A strategy for the synthesis of isoquinoline derivatives was proposed that involves a reaction of this organolead reagent with enolizable substrates followed by annelation in the presence of triphenylphosphine. The use of 2-(azidomethyl)phenylboronic acid allowed α-arylation products to be obtained from β-diketones and natural β-oxo lactones in good yields.

Key words: 2-(azidomethyl)phenylboronic acid, organolead compounds, isoquinolines, isochromanes, α-arylation, reductive coupling, lead tetraacetate.

A century after the Ullmann reactions were discovered,[1] low-toxic arylboronic acids have been recognized as ecologically attractive[2] and convenient reagents for creation of Ar—O, Ar—N, Ar—S, and Ar—C bonds.[3,4] Nevertheless, some functional groups are sensitive to both organocopper and palladium- or nickel-containing catalysts. For instance, the azido group belongs to such substituents.[5]

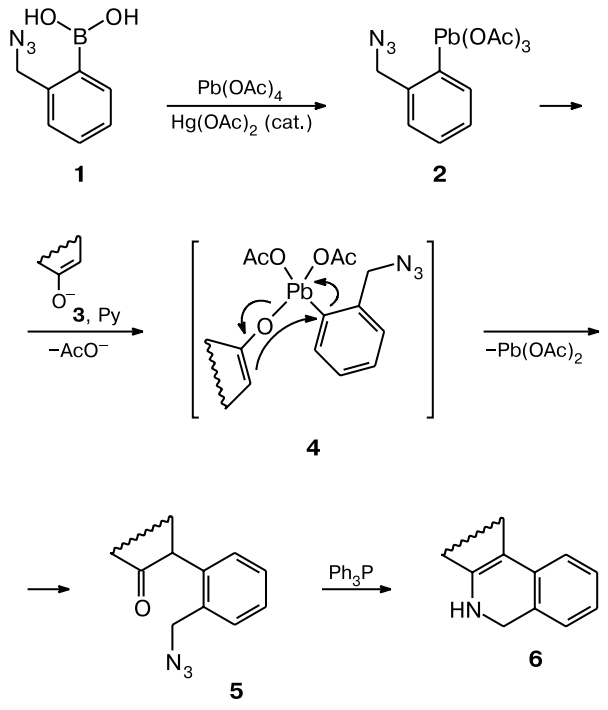
The goal of the present work was to develop azido-containing reagents for C-arylation of enolizable substrates. It was suggested that these reagents with 2-(azidomethyl)aryl fragments can be obtained from previously[6] synthesized functionalized arylboronic acids. In addition, the proposed strategy can serve as a basis for construction of the isoquinoline framework found in many natural compounds that exhibit a broad spectrum of biological activities.[7]

As an alternative to Pd-catalyzed arylation using the Suzuki cross-coupling[4] or catalytic α-arylation of enolizable substrates,[8] we introduced (azidomethyl)aryl fragments into a substrate by reductive coupling with the use of aryllead triacetates prepared from the corresponding arylboronic acids.[9] It is known that introduction of a functional group into the benzyl position of *o*-tolyllead triacetate derivatives does not change significantly their reactivities toward soft nucleophiles.[10]

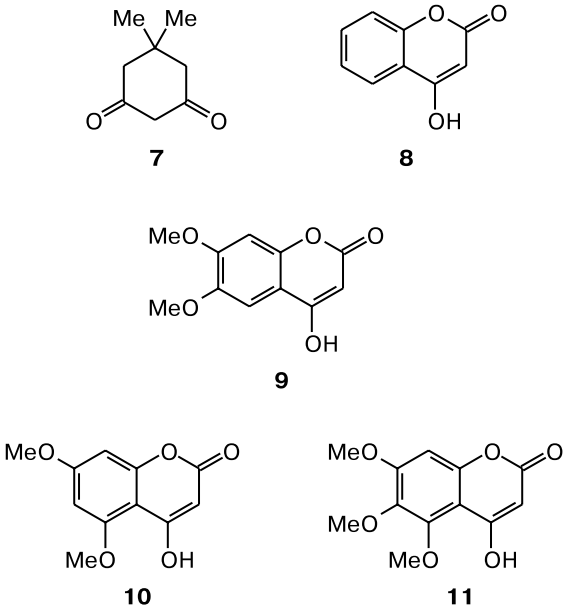
The synthesis of isoquinoline derivatives from 2-(azidomethyl)phenylboronic acid includes four successive reactions without isolation of intermediates at each step (Scheme 1). Transmetalation between arylboronic acid **1** and lead tetraacetate in the presence of a catalytic amount of mercury acetate[11] gives 2-(azidomethyl)phenyllead triacetate **2**, which can react *in situ* with enolizable substrate **3** in the presence of a base. This reductive coupling is characteristic of not only lead derivatives[9,12,13] but also aryl compounds of bismuth,[12,14] iodine,[12,15] and some other main group elements.[12] Supposedly, the process involves the formation of a covalent intermediate **4**,[16] which undergoes reductive elimination to give α-arylation product **5**. Finally, the subsequent reduction of the azido group with triphenylphosphane (Staudinger reaction[5b]) is followed by spontaneous annelation leading to isoquinoline derivatives **6**.

Published in Russian in *Izvestiya Akademii Nauk. Seriya Khimicheskaya,* No. 7, pp. 1560—1565, July, 2005.

Scheme 1

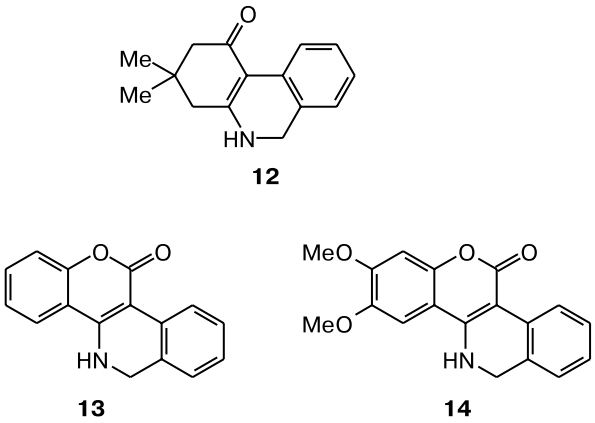


β-Diketone **7**, unsubstituted 4-hydroxycoumarin **8**, and its natural di- and trimethoxy derivatives **9**—**11** [17] were used as starting substrates.



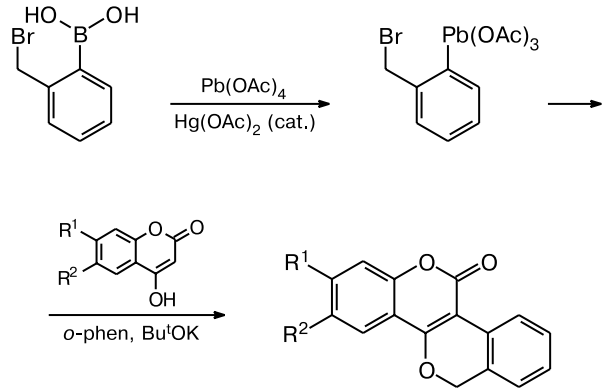
Use of the complex of 2-(azidomethyl)phenylboronic acid with DMF previously[6] obtained by the reaction of 2-(bromomethyl)phenylboronic acid with NaN_3 in DMF, did not afford any tetracyclic derivatives of the type **6** or α-arylation products **5**. However, when the reaction of 2-(bromomethyl)phenylboronic acid with NaN_3 was carried out in a THF—H_2O emulsion, the resulting free 2-(azidomethyl)phenylboronic acid **1** became reactive, giving aryllead triacetate **2** in 52% yield.

The "one-pot" synthesis from dimedone **7** in four steps afforded isoquinoline derivative **12** in 21% yield. Using this procedure with unsubstituted 4-hydroxycoumarin **8** and 4-hydroxy-6,7-dimethoxycoumarin **9**, we obtained tetracyclic derivatives **13** and **14** in overall 23 and 15% yields, respectively.



In the case of coumarins **8** and **9**, tetracyclic benzopyrans **15** and **16** were also detected among the reaction products (10 and 11% yields, respectively). To identify isoquinoline and benzopyran isostructural analogs, the latter were synthesized in an independent way (Scheme 2). For instance, the reactions of 2-(bromomethyl)phenyllead triacetate with coumarins **8** and **9** in the presence of *o*-phenanthroline—potassium *tert*-butoxide (3 : 1) as a base for reductive coupling gave compounds **15** and **16** in 76 and 47% yields, respectively.

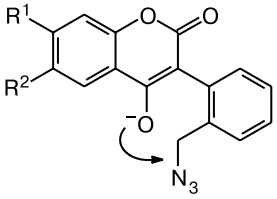
Scheme 2



15: $R^1 = R^2 = H$
16: $R^1 = R^2 = OMe$

Thus, the formation of benzopyran analogs **15** and **16** from intermediate azides **5** can be explained by the S_N2 process competing with the Staudinger reaction.

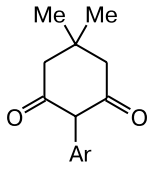
It should be noted that we failed to obtain isoquinoline derivatives from 4-hydroxy-5,7-dimethoxycoumarin **10** and 4-hydroxy-5,6,7-trimethoxycoumarin **11**. This can be explained by hydrogen bonding between the enol H atom and the O atom of the methoxy group in position 5 of the coumarin framework. Such interactions can stabilize the enol form of α-arylation product of the type **5**, thus precluding its participation in the Staudinger reaction (see Scheme 1).[18]



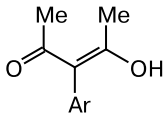
In connection with this, we decided to isolate α-arylation products **5**. Mono-α-arylation products **18** and **19** were obtained from β-diketones (dimedone **7** and acetylacetone **17**) in 31 and 52% yields, respectively. Arylation of coumarin derivatives **8**—**11** gave *iso*-flavonoids **20**—**23** in 46, 25, 41, and 50% yields, respectively. It should be noted that the ^{1}H NMR spectra of compounds **20** and **21** show two doublets for the methylene groups, while the CH_2N_3 fragments in derivatives **22** and **23** appear as singlets. This fact can be explained by the presence of hydrogen bonding between the enolic OH group and the nitrene N atom of the azido group in compounds **20** and **21**. It is known[19] that the nitrene N atom of the azido group can serve as a donor of the electron density in complexes of organic azides with Lewis acids or a proton. This is confirmed by quantum-chemical calculations that suggest the presence of weak donor—acceptor interactions between the nitrene N atom of the azido fragment and the H atoms of the hydroxy groups in 2-(azidomethyl)phenylboronic acid.[6] Such hydrogen bonding in compounds **20** and **21** can hinder the rotation about the C(3)—C(1′) bond formed by the trigonal C atoms, thus making the protons of the methylene group diastereotopic.[20] In derivatives **22** and **23**, the methoxy group in position 5 of the coumarin framework favors the formation of a competitive O—H—O hydrogen bond, which is stronger than the O—H—N interaction in compounds **20** and **21**. This allows a relatively free rotation of the aryl fragment.[18]

Finally, α-arylation product **25** was obtained from β-oxo ester, namely, ethyl 2-oxocyclohexanecarboxylate **24**, in 28% yield; unfortunately, this product was not separated from compound **24** by column chromatography.

Thus, we developed the method for introduction of benzylazido fragments into enolizable organic substrates through the use of 2-(azidomethyl)phenylboronic acid as a key reagent. This method allows the "one-pot" synthesis of isoquinoline derivatives in four successive steps. The reaction conditions will be optimized in the near future.



18



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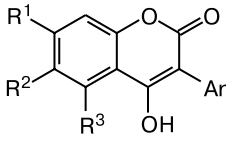
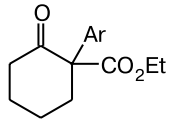
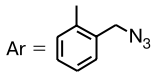


20—23



25



	20	**21**	**22**	**23**
R^1	H	OMe	OMe	OMe
R^2	H	OMe	H	OMe
R^3	H	H	OMe	OMe

Experimental

NMR spectra were recorded on a Bruker AC200 spectrometer (200.13 (^{1}H) and 50.32 MHz (^{13}C)). Chemical shifts are referenced to Me_4Si. IR spectra were recorded on a Specord 75IR spectrometer. 4-Hydroxycoumarin derivatives **8**—**11** were prepared according to known procedures.[17] Commercial $Pb(OAc)_4$, $Hg(OAc)_2$, dimedone **7**, ethyl 2-oxocyclohexanecarboxylate **24**, and *o*-phenanthroline (Lancaster) were used as purchased. Freshly distilled acetylacetone **17** was used.

2-(Azidomethyl)phenylboronic acid (1). 2-(Bromomethyl)phenylboronic acid[6] (1 g, 4.6 mmol) was dissolved in THF (7 mL) and distilled water (2 mL) was added. After addition of NaN_3 (0.9 g, 13.8 mmol) to the vigorously stirred mixture, the reaction mixture was stirred at ~20 °C for 12 h. Then Et_2O (40 mL) was added and the organic layer was washed with water (3×10 mL) and dried over anhydrous sodium sulfate. The solvent was removed under reduced pressure and the residue was recrystallized from CH_2Cl_2—light petroleum (1 : 1). Compound **1** (0.5 g, 61%) was isolated as white acicular crystals, m.p. 64 °C. Found (%): C, 47.32; H, 4.84; N, 23.91. $C_7H_8BN_3O_2$. Calculated (%): C, 47.51; H, 4.56; N, 23.74. ^{1}H NMR ($CDCl_3$), δ: 4.89 (s, 2 H, CH_2); 7.31—7.66 (m, 3 H, C(3), C(4), C(5)); 8.28 (dd, 1 H, C(6), J_1 = 7.1 Hz, J_2 = 1.2 Hz). ^{13}C NMR ($CDCl_3$), δ: 54.2 (CH_2); 128.2, 129.8, 132.9, 137.5 (C(3), C(4), C(5), C(6)); 142.3 (C(2)); no signal for the C(1) atom appeared in the spectrum.[6]

2-(Azidomethyl)phenyllead triacetate (2). A solution of 2-(azidomethyl)phenylboronic acid **1** (0.15 g, 0.84 mmol) in $CHCl_3$ (5 mL) was added dropwise in an inert atmosphere at 35 °C to a stirred mixture of lead tetraacetate (0.38 g, 0.84 mmol) and mercury diacetate (0.027 g, 0.084 mmol) in anhydrous $CHCl_3$ (3 mL). The reaction mixture was kept at this temperature for 1 h, stirred at ~20 °C for ~20 h, filtered through Celite (10—15 g) on a sintered glass filter. The Celite layer was washed with $CHCl_3$ (60 mL) and the solvent was removed under reduced pressure. The viscous residue was diluted with pen-

tane—ether (1 : 1) (7 mL) and the mixture was vigorously stirred in an ice bath. The solvent was removed and the product was recrystallized from CH_2Cl_2—light petroleum (1 : 1). Product **2** (0.22 g, 52%) was isolated as colorless crystals, m.p. (decomp.) 71 °C. Found (%): C, 30.29; H, 2.97; N, 8.01. $C_{13}H_{15}N_3O_6Pb$. Calculated (%): C, 30.23; H, 2.93; N, 8.14. ^{1}H NMR ($CDCl_3$), δ: 2.11 (s, 9 H, $CH_3C(O)$); 4.80 (s, 2 H, CH_2); 7.27—7.56 (m, 3 H, H_{arom}); 7.94 (d, 1 H, HC(6), J = 7.8 Hz). ^{13}C NMR ($CDCl_3$), δ: 20.4 ($\underline{C}H_3C(O)$); 53.0 (CH_2); 130.0, 130.9, 131.5, 131.6 (C(3), C(4), C(5), C(6)); 134.4 (C(2)); 162.1 (C(1)), 179.7 ($CH_3\underline{C}(O)$).

Synthesis of isoquinoline derivatives (general procedure). A solution of boronic acid **1** (0.112 g, 0.63 mmol) in $CHCl_3$ (2 mL) was added dropwise in an inert atmosphere at 35 °C to a stirred mixture of lead tetraacetate (0.28 g, 0.63 mmol) and mercury diacetate (0.020 g, 0.063 mmol) in anhydrous $CHCl_3$ (3 mL). The reaction mixture was stirred at this temperature for 30 min and then at room temperature for ~20 h. Dimedone (0.062 g, 0.44 mmol) and pyridine (0.104 g, 1.32 mmol) in anhydrous $CHCl_3$ (2 mL) were added and the mixture was stirred at 40 °C for 1 h and at ~20 °C for 12 h. Then Ph_3P (0.115 g, 0.44 mmol) was added and stirring was continued at 40 °C for 12 h. The solvent was removed under reduced pressure. The product was purified by column chromatography on SiO_2 with Et_2O—light petroleum (1 : 3) as an eluent.

3,3-Dimethyl-3,4,5,6-tetrahydro-2*H*-phenanthridin-1-one **12** (0.021 g, 21%) was isolated as a transparent oil. Found (%): C, 79.29; H, 7.78; N, 6.41. $C_{15}H_{17}NO$. Calculated (%): C, 79.26; H, 7.54; N, 6.16. ^{1}H NMR ($CDCl_3$), δ: 1.10 (s, 6 H, CH_3); 2.41 (s, 2 H, CH_2); 2.43 (s, 2 H, CH_2); 5.12 (s, 2 H, CH_2); 7.02 (d, 1 H, H(7), J = 7.2 Hz); 7.20—7.36 (m, 2 H, H(8), H(9)); 8.38 (d, 1 H, H(10), J = 7.6 Hz). ^{13}C NMR ($CDCl_3$), δ: 28.2 (CH_3); 31.4 (CH_2, C(3)); 42.5 (CH_2, C(4)); 52.1 (C(2)); 69.4 (CH_2, C(6)); 111.7 (C(11)); 123.6, 124.6, 126.8, 128.5 (C(7), C(8), C(9), C(10)); 126.7, 127.6 (C(13), C(14)); 172.5 (C(12)); 196.3 (C(1)). IR (Nujol), ν/cm^{-1}: 3390 (NH).

A mixture of compounds 13 and 15 was obtained by applying the general procedure to 4-hydroxycoumarin **8**. Column chromatography on SiO_2 with $CHCl_3$—Et_2O—light petroleum (2 : 2 : 1) as an eluent followed by preparative TLC on SiO_2 with the same eluent gave products **13** (0.023 g, 21%) and **15** (0.011 g, 10%).

5,6-Dihydro-11*H*-[1]benzopyrano[4,3-*c*]isoquinolin-11-one (13), colorless crystals, m.p. 138 °C. Found (%): C, 77.23; H, 4.68; N, 5.67. $C_{16}H_{11}NO_2$. Calculated (%): C, 77.10; H, 4.45; N, 5.62. ^{1}H NMR ($CDCl_3$), δ: 5.50 (s, 2 H, CH_2); 7.10 (d, 1 H, H(1), J = 7.4 Hz); 7.26 (t, 1 H, H(8), J = 6.8 Hz); 7.35—7.52 (m, 3 H, H(2), H(3), H(4)); 7.68 (dt, 1 H, H(7), J_1 = 7.4 Hz, J_2 = 1.3 Hz); 8.29 (d, 1 H, H(9), J = 7.6 Hz); 8.83 (d, 1 H, H(10), J = 7.8 Hz). ^{13}C NMR ($CDCl_3$), δ: 71.7, 98.0, 117.1, 123.6, 123.7, 125.2, 125.4, 125.8, 126.4, 127.0, 127.9, 129.0, 133.1, 152.3, 165.8, 176.0. IR (Nujol), ν/cm^{-1}: 3375 (NH).

6*H*,11*H*-[2]Benzopyrano[4,3-*c*][1]benzopyran-11-one (15), colorless crystals, m.p. 154 °C. Found (%): C, 76.85; H, 4.09. $C_{16}H_{10}O_3$ (250.25). Calculated (%): C, 76.79; H, 4.03. ^{1}H NMR ($CDCl_3$), δ: 5.41 (s, 2 H, CH_2); 7.13 (d, 1 H, H(1), J = 7.2 Hz); 7.27—7.48 (m, 4 H, H_{arom}); 7.57 (t, 1 H, H(7), J = 7.6 Hz); 7.87 (d, 1 H, H(9), J = 7.8 Hz); 8.55 (d, 1 H, H(10), J = 7.6 Hz). ^{13}C NMR ($CDCl_3$), δ: 69.7 (CH_2N_3); 116.5, 123.1, 123.9, 124.0, 124.9, 128.2, 129.0, 132.5 (C—H arom.); 102.6, 115.2, 126.6, 127.4, 152.9, 160.1 and 161.2 (quaternary C).

A mixture of compounds 14 and 16 was obtained by applying the general procedure to 4-hydroxy-6,7-dimethoxycoumarin **9**. Column chromatography on SiO_2 with $CHCl_3$—ethanol (44 : 1) as an eluent followed by preparative TLC on SiO_2 with the same eluent gave derivatives **14** (0.020 g, 15%) and **16** (0.015 g, 11%).

2,3-Dimethoxy-5,6-dihydro-11*H*-[1]benzopyrano[4,3-*c*]isoquinolin-11-one (14), colorless crystals, m.p. 158 °C. ^{1}H NMR ($CDCl_3$), δ: 3.97, 4.00 (both s, 3 H each, OMe); 5.47 (s, 2 H, CH_2); 6.84 (s, 1 H, H(5)); 7.09 (d, 1 H, H(3′), J = 6.1 Hz); 7.26 (dt, 1 H, H(4′), J_1 = 6.1 Hz, J_2 = 1.7 Hz); 7.40 (dt, 1 H, H(5′), J_1 = 6.6 Hz, J_2 = 1.8 Hz); 7.64 (s, 1 H, H(8)); 8.83 (d, 1 H, H(6′), J = 6.6 Hz). ^{13}C NMR ($CDCl_3$), δ: 56.4, 56.3, 71.67, 97.4, 99.2, 105.4, 116.8, 123.6, 125.2, 125.9, 126.9, 128.2, 128.9, 147.6, 147.8, 153.8, 165.4, 175.5. IR (Nujol), ν/cm^{-1}: 3380 (NH).

2,3-Dimethoxy-6*H*,11*H*-[2]benzopyrano[4,3-*c*][1]benzopyran-11-one (16), light yellow powder, m.p. 132 °C. Found (%): C, 68.81; H, 4.67. $C_{18}H_{14}O_5$ (310.31). Calculated (%): C, 69.07; H, 4.55. ^{1}H NMR ($CDCl_3$), δ: 3.96 (s, 6 H, OCH_3); 5.38 (s, 2 H, CH_2N_3); 6.84 (s, 1 H, H(5)); 7.21 (s, 1 H, H(8)); 7.26—7.41 (m, 3 H, H_{arom}); 8.56 (d, 1 H, H(6′), J = 7.6 Hz). ^{13}C NMR ($CDCl_3$), δ: 56.3, 56.4 (OCH_3); 69.7 (CH_2); 99.5, 103.1, 123.8, 127.0, 127.7, 129.0 (C—H arom.); 100.4, 107.2, 124.4, 146.4, 149.0, 153.6, 160.6, 160.6; 161.5 (quaternary C).

Compounds 15 and 16 (alternative synthesis). A solution of 2-(bromomethyl)phenylboronic acid[10] (0.054 g, 0.25 mmol) in $CHCl_3$ (1 mL) was added dropwise in an inert atmosphere at 40 °C to a stirred mixture of lead tetraacetate (0.111 g, 0.25 mmol) and mercury diacetate (0.008 g, 0.025 mmol) in anhydrous $CHCl_3$ (1.5 mL). The reaction mixture was kept at this temperature for 1 h and stirred at ~20 °C for 20 h. Potassium *tert*-butoxide (0.02 g, 0.21 mmol) and a solution of the appropriate 4-hydroxycoumarin (0.34 g, 0.21 mmol) and *o*-phenanthroline (0.112 g, 0.62 mmol) in anhydrous $CHCl_3$ (1.5 mL) were added. The reaction mixture was stirred at 45 °C for 4 h and left at room temperature for 20 h. The solvent was removed under reduced pressure. Products **15** and **16** were isolated by column chromatography on SiO_2 with Et_2O—light petroleum (1 : 1) for **15** and ethyl acetate—pentane (3 : 7) for **16** as eluents. The yields of compounds **15** and **16** were 76% and 47%, respectively.

Synthesis of compounds 18—23 and 25 (general procedure). A solution of acid **1** (0.4—0.6 mmol, 1 equiv.) in $CHCl_3$ (2 mL) was added dropwise in an inert atmosphere at 35 °C to a stirred mixture of lead tetraacetate (0.4—0.6 mmol, 1 equiv.) and mercury diacetate (0.04—0.06 mmol, 0.1 equiv.) in anhydrous $CHCl_3$ (3 mL). The reaction mixture was kept at this temperature for 30 min and then stirred at room temperature for 20 h. An enolizable substrate **7—11**, **17**, or **24** (0.4—0.55 mmol, 0.83 equiv.) and pyridine (1.2—1.8 mmol, 3.0 equiv.) in anhydrous $CHCl_3$ (2 mL) were added and the mixture was stirred at 40 °C for 1 h and at room temperature for 12 h. The solvent was removed under reduced pressure. The α-arylation product was isolated by column chromatography on SiO_2.

2-(2-Azidomethylphenyl)-5,5-dimethylcyclohexane-1,3-dione (18) was purified by column chromatography (SiO_2, Et_2O—light petroleum, 7 : 3). The yield of compound **18** was 31%, colorless crystals, m.p. 130—132 °C ($CHCl_3$—light petroleum). Found (%): C, 66.12; H, 6.02. $C_{15}H_{17}O_2N_3$. Calculated (%): C, 66.40; H, 6.32. ^{1}H NMR ($CDCl_3$), δ: 1.17, 1.18 (both s, 6 H, CH_3); 2.40 (d, 4 H, $CH_2C(O)$, J = 19.4 Hz); 4.16 (d, 2 H, CH_2N_3, J = 9.4 Hz); 7.06—7.13 (m, 1 H, H_{arom}); 7.30—7.49

(m, 3 H, H_{arom}). ^{13}C NMR ($CDCl_3$), δ: 28.3, 28.5 (CH_3); 29.7 (C(5)); 31.9 (C(4), C(6)); 53.2 ($\underline{CH_2}N_3$); 115.3 (C(2)); 129.2, 129.9, 131.7, 196.8 (C(3′), C(4′), C(5′), C(6′)); 130.5, 136.4 (C(1′), C(2′)); 196.8 (C(1), C(3)). IR (Nujol), ν/cm^{-1}: 2115 (N_3).

3-(2-Azidomethylphenyl)pentane-2,4-dione (19) was purified by column chromatography (SiO_2, Et_2O—light petroleum, 1 : 19). The yield of compound **19** was 52%, colorless oil. Found (%): C, 62.02; H, 5.37; N, 18.01. $C_{12}H_{13}O_2N_3$. Calculated (%): C, 62.33; H, 5.67; N, 18.17. ^1H NMR ($CDCl_3$), δ: 1.81 (s, 6 H, CH_3); 4.24 (s, 2 H, CH_2N_3); 7.10—7.21 (m, 1 H, H_{arom}); 7.36—7.43 (m, 3 H, H_{arom}); 16.68 (s, 1 H, enol OH). ^{13}C NMR ($CDCl_3$), δ: 29.4, 29.7 (CH_3); 52.8 ($\underline{CH_2}N_3$); 112.1 (C(3)); 128.6, 129.2, 129.7, 132.2 (C(3′), C(4′), C(5′), C(6′)); 135.2, 136.2 (C(1′), C(2′)); 190.9 (C(2), C(4)). IR (Nujol), ν/cm^{-1}: 2100 (N_3).

3-(2-Azidomethylphenyl)-4-hydroxycoumarin (20) was purified by column chromatography (SiO_2, Et_2O—light petroleum, 4 : 1). The yield of compound **20** was 45%, colorless crystals, m.p. 173—174 °C ($CHCl_3$—light petroleum). Found (%): C, 65.24; H, 3.47; N, 14.16. $C_{16}H_{11}O_3N_3$. Calculated (%): C, 65.53; H, 3.78; N, 14.33. ^1H NMR ($CDCl_3$), δ: 4.28 (d, 1 H, $C\underline{H}_aH_bN_3$, J = 14.0 Hz); 4.38 (d, 1 H, $CH_a\underline{H}_bN_3$, J = 14.0 Hz); 7.30—7.63 (m, 7 H, H_{arom}); 7.93 (dd, 1 H, H_{arom}, J_1 = 7.6 Hz, J_2 = 1.2 Hz). ^{13}C NMR ($CDCl_3$), δ: 52.9 (CH_2N_3); 104.5, 114.8, 128.5, 137.0, 153.2, 160.8, 161.7 (quaternary C); 117.0, 123.8, 124.2, 129.4, 130.1, 130.2, 131.7, 132.8 (C—H_{arom}). IR (Nujol), ν/cm^{-1}: 2090 (N_3), 3210 (OH).

3-(2-Azidomethylphenyl)-4-hydroxy-6,7-dimethoxycoumarin (21) was purified by column chromatography (SiO_2, Et_2O—light petroleum, 1 : 1). The yield of compound **21** was 25%, colorless crystals, m.p. 176—177 °C ($CHCl_3$—light petroleum). Found (%): C, 60.90; H, 3.97; N, 12.01. $C_{18}H_{15}O_5N_3$. Calculated (%): C, 61.19; H, 4.28; N, 11.89. ^1H NMR ($CDCl_3$), δ: 3.93, 3.99 (both s, 6 H, OCH_3); 4.26 (d, 1 H, $C\underline{H}_aH_bN_3$, J = 14.3 Hz); 4.38 (d, 1 H, $CH_a\underline{H}_bN_3$, J = 14.3 Hz); 6.83 (s, 1 H, H(5)); 6.94 (s, 1 H, H(8)); 7.31—7.50 (m, 4 H, H_{arom}). ^{13}C NMR ($CDCl_3$), δ: 56.5, 56.6 (OCH_3); 67.9 ($\underline{CH_2}N_3$); 100.1, 103.4 (C(5), C(8)); 108.4, 115.6, 129.8, 135.5, 149.4, 154.1, 156.8, 161.4, 166.6 (quaternary C); 128.1, 128.7, 129.4, 130.5 (C(3′), C(4′), C(5′), C(6′)). IR (Nujol), ν/cm^{-1}: 2095 (N_3), 3205 (OH).

3-(2-Azidomethylphenyl)-4-hydroxy-5,7-dimethoxycoumarin (22) was purified by column chromatography (SiO_2, Et_2O—light petroleum, 1 : 1) and additionally by preparative TLC with $CHCl_3$—EtOH (44 : 1) as an eluent. The yield of compound **22** was 41%, colorless crystals, m.p. 185 °C ($CHCl_3$—light petroleum). Found (%): C, 60.90; H, 3.99; N, 11.72. $C_{18}H_{15}O_5N_3$. Calculated (%): C, 61.19; H, 4.28; N, 11.89. ^1H NMR ($CDCl_3$), δ: 3.88, 4.02 (both s, 6 H, OCH_3); 4.34 (s, 2 H, CH_2N_3); 6.40 (d, 1 H, H(6), J = 2.1 Hz); 6.55 (d, 1 H, H(8), J = 2.1 Hz); 7.29—7.43 (m, 4 H, H_{arom}); 9.60 (br.s, 1 H, OH). ^{13}C NMR ($CDCl_3$), δ: 53.0 (CH_2N_3); 56.1, 57.1 (OCH_3); 94.4, 95.8, 98.6, 101.8, 128.3, 128.6, 128.9, 130.9, 131.8, 135.5, 156.1, 157.3, 162.2, 162.5, 163.5. IR (Nujol), ν/cm^{-1}: 3205 (OH), 2095 (N_3).

3-(2-Azidomethylphenyl)-4-hydroxy-5,6,7-trimethoxycoumarin (23) was purified by column chromatography (SiO_2, Et_2O—light petroleum, 1 : 1) and additionally by preparative TLC with $CHCl_3$—EtOH (44 : 1) as an eluent. The yield of compound **23** was 50%, colorless crystals, m.p. 168 °C ($CHCl_3$—light petroleum). Found (%): C, 59.31; H, 4.28; N, 10.68. $C_{19}H_{17}O_6N_3$. Calculated (%): C, 59.53; H, 4.47; N, 10.96. ^1H NMR ($CDCl_3$), δ: 3.88, 3.95, 4.17 (all s, 9 H, OCH_3); 4.33 (s, 2 H, CH_2N_3); 6.72 (s, 1 H, H(8)); 7.30—7.51 (m, 4 H, H_{arom}); 10.10 (br.s, 1 H, OH). ^{13}C NMR ($CDCl_3$), δ: 52.9, 56.4, 61.4 (OCH_3); 62.8 ($\underline{CH_2}N_3$); 96.7 (C(8)); 128.2, 128.6, 128.9, 131.6 (C(3′), C(4′), C(5′), C(6′)); 100.7, 102.6, 130.6, 135.4, 137.5, 149.1, 150.4, 157.3, 162.1 (quaternary C). IR (Nujol), ν/cm^{-1}: 2090 (N_3), 3190 (OH).

This work was financially supported by the Russian Foundation for Basic Research (Project No. 02-03-33021), the Competitive Center of Basic Natural Sciences (Project No. PD02-1.3-443), and the INTAS (Grant 03-514915).

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Received February 11, 2005;
in revised form May 26, 2005