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Functiaonalization of 2-(1-Cyclohexen-1-yl)aniline Derivatives

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Abstract—The reaction of 2-(1-cyclohexen-1-yl)aniline and -6-methylaniline with phthalic anhydride has afforded 2-(2-cyclohex-1-en-1-ylphenyl)- and 2-(2-cyclohex-1-en-1-ylphenyl)-6-methylphenyl)-1*H*-isoindole-1,3(2*H*)-diones. The reaction of the obtained isoindole-1,3-diones with bromine in dichloromethane in the presence of sodium bicarbonate has led to the formation of the product of pseudo-allylic halogenation. Replacement of the halogen atom by methoxy group has been performed by keeping 2-[2-(6-bromocyclohex-1-en-1-ylphenyl)-6-methylphenyl)]-1*H*-isoindole-1,3(2*H*)-dione in a methanolic solution in the presence of $NaHCO_3$. The reaction of 2-(2-cyclohex-1-en-1-yl-6-methylphenyl)-1*H*-isoindole-1,3(2*H*)-dione with molecular bromine in the presence of methanol has given a co-halogenation product, whereas the dibromination product has been obtained in the presence of octyl alcohol.

Keywords: isoindolediones, methoxylation, bromination, phthalimides, atropisomer

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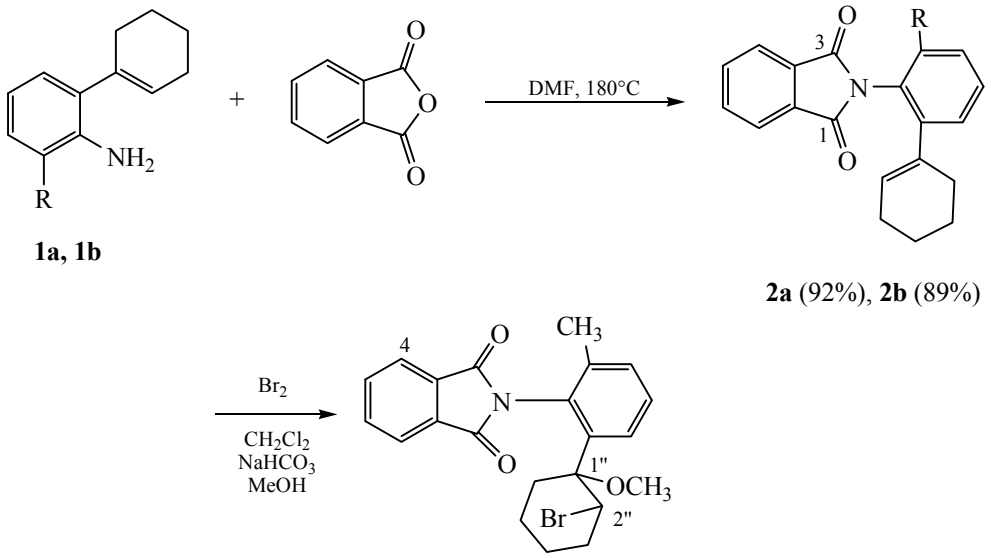
Several approaches of preparative introduction of allyl [1, 2], homoallyl [3], and vinyl [4–6] substituents in benzene core have been developed. For example, many aminoaryl-substituted unsaturated hydrocarbons [7] with *ortho*- [8, 9], *meta*- [10], and *para*-positions [11] of amine, alkene and cycloalkene fragments in the aromatic ring as well as theirs derivatives with amino and oxy groups at alkene [12, 13] and *N*-alkenylaniline [14, 15] have become available. Many of these compounds have been applied in organic synthesis [16]. For example, biologically active arylamides [17], acidic corrosion inhibitors [18], antiviral [19, 20] and antitumoral drugs have been synthesized basing on these substances [21].

Chemical transformations of several *N*-tosyl(mesyl)-2-(1-cycloalkene-1-yl)aniline substituents via the interaction with conventional electrophilic reagents might differ from the classical concepts. Such transformations occurs in the reactions of the said sulfonylamides with molecular bromine in the presence of hydrocarbonates or methanolic solution of copper dibromide, resulting in the formation of pseudo-allyl bromination [22–24] or methoxylation [25] products, which can be used in the synthesis of carbazoles with different hydrogenation patterns. The drawback of these schemes is the removal of protecting tosyl and mesyl groups in aggressive media, which may be accompanied by undesired transformation of other functional groups. The use of protectors which can be removed easier in comparison with aryl- and alkylsulfonyl ones can lead to different results. In particular, attempts to functionalize cycloalkene fragments of *N*-acetyl- and *N*-alkoxycarbonyl-substituted analogs in a similar way, via the interaction with bromine [26] or peroxides [27], has led to the formation of benzoxazines. In view of the above, the investigation of protecting groups which allow convenient useful functionalization of cycloalkene fragment yet can be easily removed from the nitrogen atom has become an emerging field of research.

In this study, we synthesized phthalimide derivatives of 2-(1-cyclohexene-1-yl)-phenyl-1,3-isoindoledione and investigated theirs reactions with bromine under different conditions. Phthalyl group [29] is among the most commonly used ones for the amine protection in the synthetic schemes involving amino acids [28]. Phthalyl group is applicable in the cases of relatively thermally stable amines, since their interaction with

Scheme 1.



1a, 1b

2a (92%), **2b** (89%)

4 (36%)

R = H (**a**), CH_3 (**b**).

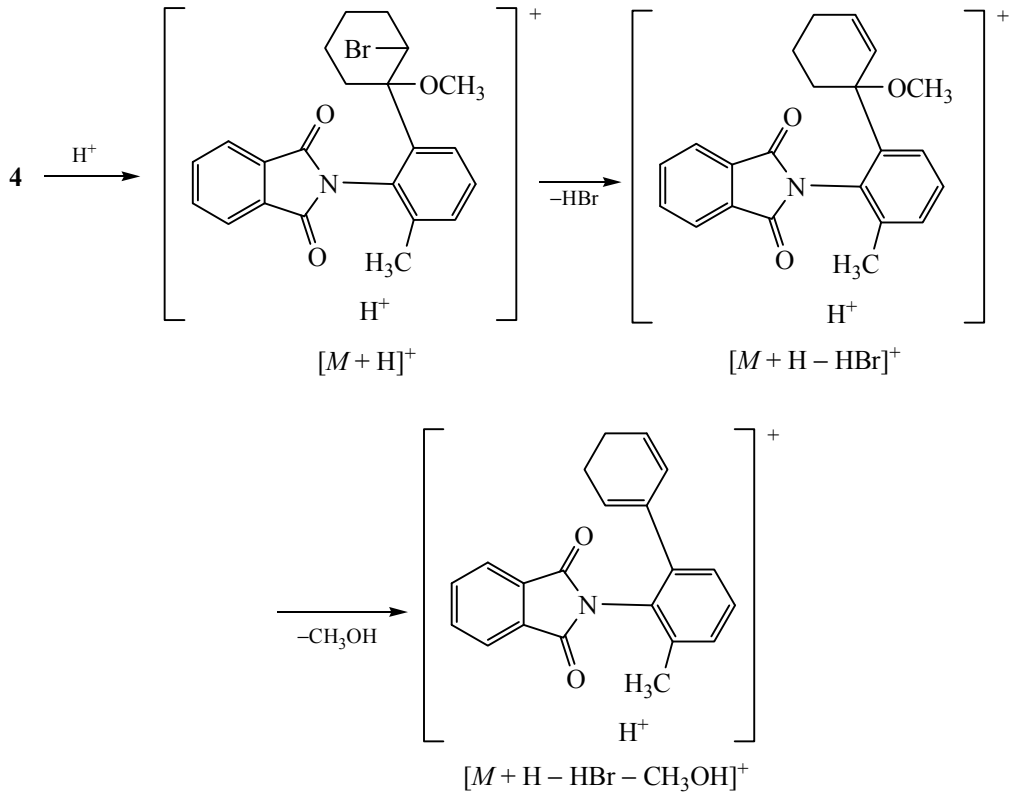
phthalic anhydride occurs at high temperature [30, 31] but this group can be removed via the treatment with hydrazine under mild conditions [32]. Amines **1a**, **b** used in this study exhibited high thermal stability. They were obtained via heating of 2-(2-cyclohexen-1-yl)aniline and its 6-methyl-substituted homolog, respectively, with KOH at 300°C as reported elsewhere [33]; physico-chemical parameters of the products coincided with the reference values [22, 33, 34]. Isoindolones **2a**, **b** were synthesized via boiling of the corresponding cyclohexenylanilines **2a** [33, 34], **2b** [22] with phthalic anhydride in DMF (Scheme 1). The reaction products were isolated by chromatography on silica gel.

Comparison of the results of bromination of the synthesized 2-[2-(1-cyclohexen-1-yl)]-6-methylphenyl-1-indole-2,3-dione **2b** (Scheme 1) and bromine interaction with *N*-tosylate **3a** [22, 25, 34, 35] or *N*-mesylate **3b** [22] (Scheme 2) under the same conditions reported previously showed significant influence of protecting group at the nitrogen atom on the direction of the reaction. Unlike the reaction of tosylate **3a** or mesylate **3b** with halogen in the presence of methanol [25], the interaction of compound **2** with molecular bromine under the same conditions led to the product of cohalogenation **4** with methoxy group at the 1" atom of the cyclohexane fragment (Scheme 1), which was confirmed by the presence of the signals of the $C^{1"}$ carbon atom (singlet with chemical shift δ 79.34 ppm) and the bromine-substituted carbon atom C^2 (doublet at δ 51.05 ppm) in ^{13}C NMR spectrum. According to the HSQC and HMBC data, the three-proton singlet signal of the carbon atom of the OCH_3 substituent (quartet at δ 55.01 ppm), corresponded to the signal at δ 2.94 ppm. Mass spectrum of compound **4** showed the signals with *m/z* 428 and 430 (80% peak intensity), which corresponded to the molecular ion $[M + H]^+$ decomposing with the loss of halogen atom yielding the fragment with *m/z* 348 (100%), which was subsequently degraded into the fragment with *m/z* 316 (*I* = 68%) (Scheme 2).

We have previously shown that *N*-tosyl- and *N*-mesyl-substituted analogs **3a**, **b** are transformed into ethers **5c**, **d** during the interaction with $CuBr_2$ in methanol (Scheme 3) [22, 25]. Unlike this, keeping compounds **2a**, **b** in copper dibromide solution in MeOH did not lead to the transformations of those imides. *N*-acetyl- (**3e**) [33] and *N*-ethoxycarbonyl-substituted (**3f**) cyclohexenylanilines were not transformed into the products of pseudoallyl methoxylation **5e**, **f** under similar conditions as well (Scheme 3).

An attempt to obtain the compound analogous to ether **4** and bearing the octyloxy group at the 1" carbon atom of cyclohexane ring led to the product of dihalogenation. During the interaction of compound **2b** with molecular bromine in methylene chloride in the

Scheme 2.

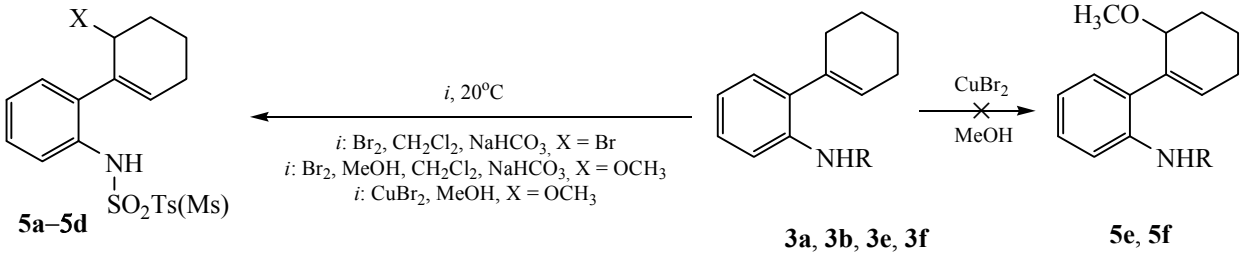


presence of octyl alcohol, compound **6** with two bromine atoms at the cyclohexane ring (Scheme 4) was formed; its structure was confirmed by ^{1}H and ^{13}C NMR spectroscopy. Aliphatic carbon atom range of the ^{13}C NMR spectrum was simple and easy to be assigned: there were seven signals corresponding, according to their multiplicity, to the CH_3 group (18.12 ppm), methylene chain $(CH_2)_4$ of the cyclohexane ring (triplets at 19.76, 20.81, 30.53, and 32.72 ppm), $C^{2''}$ carbon atom (doublet at 57.17 ppm), and $C^{1''}$ quaternary carbon atom (singlet at 74.90 ppm). The signals assignment to the listed groups was made on the basis of NMR HSQC and HMBC data.

Compound **6** was unstable under the conditions of chemical ionization under atmospheric pressure (APCI) and decomposed with the formation of the fragment **7** with *m/z* 316 $[M - 2HBr + H]^+$ (60%) and associate **8** composed of that fragment with water $[M - 2HBr + H_2O + H]^+$ (100%) with *m/z* 334 (Scheme 5).

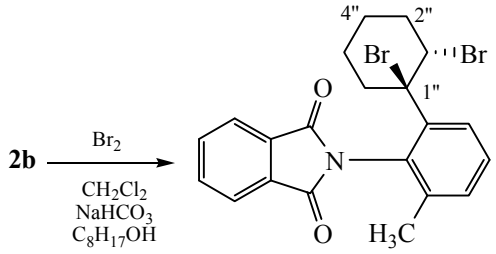
The interaction of compounds **2a**, **b** with molecular bromine in CH_2Cl_2 in the presence of $NaHCO_3$ gave the products of monobromination **9a**, **b** with high yield (Scheme 6). Molecular ion $[M + H]^+$ of compound **9b** was unstable under the conditions of APCI experiment, due the presence of labile allyl bromine atom,

Scheme 3.



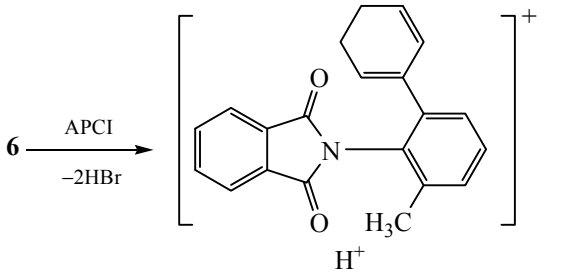
X= Br (**5a**, **5b**), OCH_3 (**5c**, **5d**); R = Ts (**3a**), Ms (**3b**), Ac (**3e**, **5e**), OCOEt (**3f**, **5f**).

Scheme 4.



6 (56%)

Scheme 5.



7, *m/z* 316 (60%) $[M - 2HBr + H]^+$

H_2O

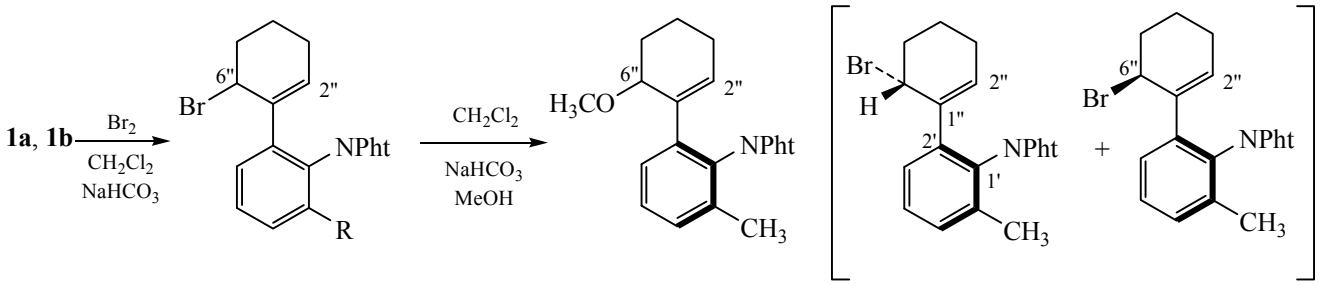
8, *m/z* 334 (100%)$[M - 2HBr + H_2O + H]^+$

and the peak of that ion was absent. In the mass spectrum, the $[M - Br]^+$ fragment with *m/z* 316 (100%) was observed, it formed the associate with water $[M - Br + H_2O]^+$ with *m/z* 334 (10%).

The latter compound should have been a racemate of *syn*- and *anti*-isomers **9** (Scheme 6) due to steric features caused by close bulky substituents at aromatic and cyclohexene rings. Preliminary theoretical analysis using Hyperchem [36] software allowed elucidation of mutual orientation of phthalimide and aromatic cycles which was almost perpendicular in the hypothetical *anti*-isomer **9**. In the case of *syn*-isomer, the dihedral angle was smaller (≈40°). At the same time, the aliphatic chain of cyclohexene fragment and aromatic ring were not coplanar as well the $C^{2"}C^{1"}C^{2'}C^{1'}$ dihedral angle being >40° for both isomers. Yet, there was no experimental confirmation of the presence of the atropoisomers. Probably, the energy barrier of the rotation about the carbon-carbon bond between the sp^2-hybridized atoms ($C^{6'}$–$C^{1"}$) in monobromide **9** was too low to manifest deceleration of the axial rotation in the NMR spectra.

Heating of compound **9b** in MeOH gave methyl ether **10** is formed (Schemes 4, 6). A distinct feature of the ^{13}C NMR spectra of compounds **9a**, **9b** and **10** was the presence of a single set of the signals of the symmetrical phthalimide moiety. Simulation of the molecules of compounds **9a**, **9b**, and **10** using Hyperchem software revealed almost parallel orientation of isoindoledione and cyclohexene rings. At the same time, each symmetrical group of the phthalimide fragment was close to different carbon atoms of the cyclohexene ring, resulting in the nonequivalent magnetic surrounding. More detailed ^1H and ^{13}C NMR signals assignment performed basing on the HSQC experiment data and using compound **9b** as example showed that the chemical shifts of pairwise symmetrical phthalimide carbon atoms $C^{4,5,6,7}$ differed insignificantly (≈0.09 ppm). After heating compound **9b** in methanol, the signal of the $H^{6"}$ proton (4.75 ppm) disappeared, while a singlet signal of the $H^{6"}$ proton was present at 3.67 ppm in ^1H NMR spectrum of the only reaction product **10**. The presence of the methoxy group in the compound **10** was confirmed by the presence of a three-proton singlet at 3.20 ppm in the

Scheme 6.



9a (90%), **9b** (97%)

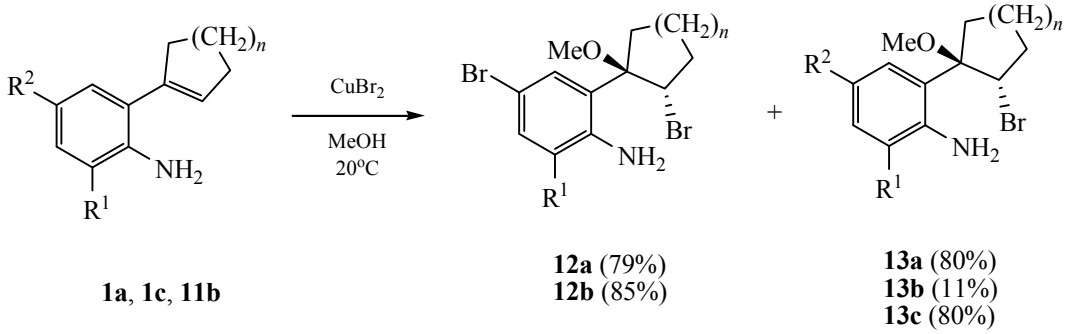
10, 86%

anti-**9a**, **9b**

syn-**9a**, **9b**

R = H (**a**), CH_3 (**b**).

Scheme 7.



1a, **1c**, **11b**

12a (79%)
12b (85%)

13a (80%)
13b (11%)
13c (80%)

$R^1 = R^2 = H$, $n = 2$ (**a**), $R^1 = CH_3$, $R^2 = H$, $n = 1$ (**b**), $R^1 = CH_3$, $R^2 = (Z)$-CH_3-CH-CH=CH-CH_3, $n = 2$ (**c**).

^{1}H NMR spectrum. ^{13}C NMR spectrum (JMOD mode) of compound **10** contained the signals of carbon atoms of methoxy group and $C^{6''}$ at 56.95 and 75.63 ppm, respectively. The signals of carbon atoms of three methylene groups appeared at δ 16.60, 25.46, and 26.56 ppm. The proton signals assignment to the carbon groups was also confirmed by HSQC, HMBC, and H–H correlation NMR data. The molecular ion $[M + H]^+$ of compound **10**, formed under conditions of the APCI experiment (*m/z* 348) was poorly stable. Low intensity of that ion peak (about 10%) could be explained by fast decay according to the $[M - CH_3OH + H]^+$ scheme yielding the fragment with *m/z* 316 (100%).

Cycloalkenylanilines **1a** [33, 34], **1c** [37] and **11b** [38] formed haloethers **12**, **13** in the reaction with copper(II) bromide in methanol (Scheme 7). The use of 4-(1-methylbut-2-en-1-yl)cyclohexenylaniline **1c** under those conditions led to the formation of the only compound **13c** with high yield. In the case of the analogs **1a** and **11b**, the proton substitution with the halogen atom at the *para*-position of the aromatic ring was possible depending on the $CuBr_2$ amount, on top of the formation of the haloether. The interaction of compound **11b** with 2 eq. of $CuBr_2$ in methanol gave dibromide **12b** and monobromide **13b**. The interaction of cyclohexenyl homolog **1a** with 1 eq. of copper(II) bromide gave haloether **13a** with high yield, whereas *para*-bromo-substituted ether **12a** was also formed in significant amount when using 2 eq. of $CuBr_2$.

The structure of the obtained compounds was elucidated by spectral methods, the composition was confirmed by elemental analysis. For example, the presence of the primary amino group in the structure of compounds **12a**, **12b** and **13a**–**13c** was evidenced by the presence of the characteristic signal at 3360–3370 and 3445–3460 cm^{-1} in the IR spectrum. The $H^{2'}$ proton gave rise to a doublet of doublets of doublets at 5.05–5.08 ppm with the spin-spin interaction constants $J_1 = 1.2$, $J_2 = 1.6$, and $J_3 = 6.3$ Hz in ^{1}H NMR spectrum of compounds **12b** and **13b**. The double resonance data revealed that the larger constant ($J_3 = 6.3$ Hz) of the proton $H^{2'}$ was due to the interaction with one of the protons of the $C^{3'}H_2$ group, and the multiple signal of that group was present in ^{1}H NMR spectra of both amino ethers **12b** and **13b** at 2.65–2.82 ppm. Replacement with halogen at the *para*-position was determined by the presence of the doublet signals of the H^3 and H^5 protons of the aromatic ring of compound **12a**. The presence of heteroatoms (bromine, methoxy group, etc.) between such aromatic protons enhanced their interaction (the W-system effect) with spin-spin interaction constant up to 3.0 Hz, as known from numerous examples. The aliphatic carbon region of the ^{13}C NMR (JMOD) spectra of compounds **12b** and **13b** contained 7 signals; those at 92.5 and 92.8 ppm corresponded to the $C^{1'}$ atom according to multiplicity and chemical shift. The signals at 54.0 and 54.5 ppm were assigned to the methoxy group, the signals of bromine-substituted carbon atom $C^{2'}$ of compounds **12b** and **13b** were at 51.1 and 51.4 ppm, respectively. Chemical shifts of three triplet signals of the methylene groups in the cyclopentane unit corresponded to the calculated values. ^{13}C NMR spectra of compounds **12a**, **13a**, and **13c** contained the signals of the methoxy carbon atoms at 54.0 ppm, and the $C^{1'}$ carbon atoms adjacent to that group were present at 81.0 ppm.

In summary, 2-(2-cyclohex-1-en-1-ylphenyl)- and 2-(2-cyclohex-1-en-1-yl-6-methylphenyl)-1*H*-isoindole-1,3(2*H*)-dione were synthesized via the interaction of 2-(2-cyclohex-1-en-1-yl)aniline and 2-(2-cyclohex-1-

en-1-yl)-6-methylaniline with phthalic anhydride with high yields. The reaction of the latter product with bromine in the presence of MeOH led to the product of cohalogenation, and vicinal dibromide was obtained in the presence of octanol. An efficient approach to obtain the product of pseudoallyl halogenation of both imides via the interaction with bromine which could be applicable to polyheterocycles synthesis was proposed. Keeping 2-(1-cyclopenten-1-yl)-6-methyl-, 2-(1-cyclohexen-1-yl)-4-(1-methylbut-2-en-1-yl)-6-methyl-, and 2-(1-cyclohexen-1-yl)aniline in a solution of $CuBr_2$ in MeOH gave the corresponding 2-(1-methoxy-2-bromo-1-cycloalkyl)anilines and the products of their further *para*-bromination. At the same time, the mentioned phthalimides of cyclohexenyl derivatives were intact in a methanolic solution of copper dibromide.

EXPERIMENTAL

The experiments were performed using the equipment of the Center for Collective Usage "Chemistry" of Ufa Institute of Chemistry, RAS. IR spectra were registered using an IR Presstige-21 spectrometer (Shimadzu). ^{1}H and ^{13}C-NMR spectra were registered using a Bruker AM 300 spectrometer operating at 300.13 and 75.73 MHz, respectively, and a Bruker Avance III instrument at (500.13 and 125.13 MHz, respectively) in $CDCl_3$ [internal reference: TMS). GLC monitoring of the reaction products purity was performed using a Chrom-5 chromatograph (carrier gas: helium, 50 mL/min, flame ionization detector, 1200×3 mm columns, stationary phase: silicone liquid SE-30 (5%) on Chromaton N-AW DMCS, operating temperature 50–300°C]. Elemental analysis were performed using a CHNS Elemental Analyzer EURO EA-3000 device. Halogen content was determined via the Schoeniger method followed by potentiometric titration. Elemental analysis data coincided with the calculated values. Column chromatography was performed on MN Kisielgel 60 silica gel (40–100 μm). Qualitative TLC analysis was performed using Sorbfil plates (Sorbpolimer, Krasnodar, Russia) developed with iodine vapor.

2-(2-Cyclohex-1-en-1-ylphenyl)-1*H*-isoindole-1,3(2*H*)-dione (2a). A solution of compound **1a** (1.73 g, 10 mmol) and phthalic anhydride (1.48 g, 10 mmol) in 5 mL of DMF was heated at 180°C for 12 h. The solvent was evaporated under reduced pressure; then 5 mL of water was added to the reaction mixture, the substance was triturated, and water was removed by filtration. The residue was purified via column chromatography on silica gel (15 g, eluent: C_6H_6). The obtained viscous substance was triturated with petroleum ether, the precipitate was filtered off and dried. Yield 2.78 g (92%). ^{1}H NMR spectrum, δ, ppm: 1.41–1.48 m, 1.57–1.63 m, 1.79–1.87 m, 2.20–2.29 m (4×2H, 4CH_2), 2.21 s (3H, CH_3), 5.50 br. s (1H, $H^{2"}$), 7.25 d (1H, H_{Ar}, J = 7.9 Hz), 7.34–7.46 m (2H, H_{Ar}), 7.78 d. d (2H, H_{Ar}, J = 3.0, J = 5.0 Hz), 7.94 d. d (2H, H_{Ar}, J = 3.0, J = 5.0 Hz).

2-(2-Cyclohex-1-en-1-yl-6-methylphenyl)-1*H*-isoindole-1,3(2*H*)-dione (2b) was obtained similarly from compound **1b** (1.87 g, 10 mmol) and 1.48 g (10 mmol) of phthalic anhydride. Yield 2.82 g (89%), colorless crystals, mp 99–102°C, R_f 0.77 ($CHCl_3$). IR spectrum, ν, cm^{-1}: 1741, 1715, 1462, 1378, 721. UV spectrum (CH_3CN), λ_{max}, nm: 268 (ε = 12000). ^{1}H NMR spectrum, δ, ppm: 1.35–1.45 m, 1.50–1.60 m, 1.75–1.85 m, 2.12–2.20 m (4×2H, 4CH_2), 2.21 s (3H, CH_3), 7.95 s (2H, $H^{5,6}$), 7.89–7.98 s and 7.74–7.83 s (2H, H^4, H^7), 7.27–7.38 t (1H, $H^{4'}$, J = 15.2 Hz) 7.24 d (2H, H^3, H^5, J = 7.3 Hz), 7.13 d (1H, H_{Ar}, J = 7.3 Hz), 5.48 s (1H, $H^{2"}$). ^{13}C NMR spectrum, δ_C, ppm: 18.30 (CH_3), 21.77, 23.01, 25.27, 29.52 ($C^{3"}$, $C^{4"}$, $C^{5"}$, $C^{6"}$), 123.52 (C^4, C^7), 126.10, 126.54, 129.01, 129.15 ($C^{3'}$, $C^{4'}$, $C^{5'}$, $C^{2"}$), 128.23, 132.04, 135.97, 137.13 (C^{3a}, C^{7a}, $C^{1"}$, $C^{2'}$, $C^{6'}$), 134.08 (C^5, C^6), 144.38 ($C^{1'}$), 167.65 (C^1, C^3). Mass spectrum, *m/z* (I_r, %): 318 (100) $[M + H]^+$.

Ethyl-(2-cyclohex-1-en-1-ylphenyl)carbamate (3f). A solution of 2.72 g (25.0 mmol) of ethyl chloroformate in 10 mL of CH_2Cl_2 was added dropwise to a suspension of 3.8 g (22.1 mmol) of amine **1a** and 4.14 g K_2CO_3 in 20 mL CH_2Cl_2 at vigorous stirring, the reaction course was monitored by TLC. 3 h after the reaction was complete, 20 mL of H_2O and 30 mL of CH_2Cl_2 were added, the mixture was stirred for 10 min, the organic phase was separated and dried over Na_2SO_4. The solvent was evaporated, the residue was purified by column chromatography silica gel (150 g, eluent: petroleum ether–C_6H_6, 1 : 1). Yield 4.75 g (86%), R_f 0.3 (150 g, eluent: petroleum ether–C_6H_6, 1 : 1). IR spectrum ν, cm^{-1}: 3320 (NH). ^{1}H NMR spectrum, δ, ppm: 1.33 t (3H, CH_3), 1.70–1.75 m, 1.77–1.82 m, 2.18–2.25 m (3×2H, CH_2), 4.19 q (2H, OCH_2, J = 7.1 Hz), 5.70–5.73 m (1H, $H^{2'}$), 6.82 br. s (1H, H_{Ar}), 6.95 d. t (1H, H_{Ar}, J = 1.0, J = 7.5 Hz), 7.01 d. d (1H, H_{Ar}, J = 1.6, J = 7.5 Hz), 7.16 d. t (1H, H_{Ar}, J = 1.6, J = 7.5 Hz), 7.99 br. s (1H, NH). ^{13}C NMR spectrum, δ_C, ppm: 14.68 (CH_3), 21.99, 23.00, 25.34, 29.95 (4 CH_2), 60.76 (OCH_2), 122.57, 127.49, 128.00, 128.11 (C^3, C^4, C^5, C^6), 134.43, 135.91 (C^1, C^2),

153.00 (NCO_2). Mass spectrum, *m/z* (I_{rel}, %): 246.0 (100) $[M + H]^+$, 244.2 (100) $[M - H]^-$.

2-{2-[(1*R,2*S**)-2-Bromo-1-methoxycyclohexyl]-6-methylphenyl}-1*H*-isoindole-1,3(2*H*)-dione (4).** 2 mL of MeOH and 0.42 g (5 mmol) of $NaHCO_3$ were added to a solution of **2b** (0.317 g, 1.0 mmol) in 5 mL of CH_2Cl_2. 0.16 g (0.052 mL, 1 mmol) of Br_2 in 2 mL of CH_2Cl_2 was slowly added to that mixture under vigorous stirring. The reaction mixture were stirred until the solution become colorless, then the solution was diluted with 30 mL of H_2O at stirring and extracted with 70 mL of CH_2Cl_2. The organic phase was dried over Na_2SO_4. The solvent was evaporated under reduced pressure, the residue was chromatographed on column with 10 g of silica gel (eluent: benzene) and crystallized from EtOH. Total yield 0.115 g (36%), colorless crystals, mp 110–112°C (EtOH), R_f 0.64. IR spectrum, ν, cm^{-1}: 1747, 1463, 1372, 1089, 1040. ^1H NMR spectrum, δ, ppm: 1.50–2.00 m (6H, CH_2), 2.46 s (3H, CH_3), 2.94 s (3H, OCH_3), 3.82 s (1H, $H^{2'''}$), 7.21 d (1H, H_{Ar}, J = 7.8 Hz), 7.24 d. t (1H, H_{Ar}, J = 1.6, J 7.8 Hz), 7.29 d. d (1H, H_{Ar}, J = 1.0, J = 7.8 Hz), 7.58 d. t (1H, H_{Ar}, J = 2.0, J = 7.4 Hz), 7.65–7.80 m (2H, H_{Ar}), 7.91 d. t (1H, H_{Ar}, J = 1.0, J = 7.6 Hz). ^{13}C NMR spectrum, δ_C, ppm: 18.82 (CH_3), 19.15, 20.41, 29.95, 30.32 ($C^{3''}$, $C^{4''}$, $C^{5''}$, $C^{6''}$), 51.05 ($C^{2''}$), 55.01 (OCH_3), 79.34 ($C^{1''}$), 121.95, 124.56, 124.96, 126.07, 130.35, 131.13, 133.09 (C^4, C^5, C^6, C^7, $C^{3'}$, $C^{4'}$, $C^{5'}$), 106.88, 129.95, 130.29, 133.10, 139.19, 143.77 (C^{3a}, C^{7a}, $C^{1'}$, $C^{2'}$, $C^{6'}$), 163.99 (C^1, C^3). Mass spectrum, *m/z* (I_{rel}, %): 428 (100) $[M + H]^+$.

2-{2-[(1R*,2S*)-1,2-Dibromocyclohexyl]-6-methylphenyl}-1*H*-isoindole-1,3(2*H*)-dione (6). 1 mL (5.0 mmol) of $C_8H_{17}OH$ and 0.42 g (5 mmol) of $NaHCO_3$ were added to a solution of **2b** (0.317 g, 1.0 mmol) in 5 mL of CH_2Cl_2. Solution of 0.16 g (0.052 mL, 1 mmol) of Br_2 in 2 mL of CH_2Cl_2 was slowly added dropwise to that mixture under vigorous stirring. The reaction mixture was stirred until the solution became colorless, diluted with 30 mL of H_2O at stirring, and extracted with 70 ml CH_2Cl_2. The organic phase was dried over Na_2SO_4. The solvent was evaporated under reduced pressure, the residue was chromatographed on a column with silica gel (10 g, eluent: C_6H_6). The obtained viscous substance was triturated with petroleum ether, the white precipitate was filtered off and dried. Yield 0.27 g (56%), mp 135–140°C (petroleum ether), R_f 0.33 ($CHCl_3$). IR spectrum, ν, cm^{-1}: 1699, 1460, 1380, 1148, 886. ^1H NMR spectrum, δ, ppm: 1.45–1.51 m, 1.65–1.69 m, 1.71–1.80 m, 1.83–1.87 m, 2.15–2.20 m, 2.75–2.83 m (4×2H, $4CH_2$), 2.10 s (3H, CH_3), 4.33 s (1H, $H^{2''}$), 7.33 d (1H, H_{Ar}, J = 7.2 Hz), 7.38 t (1H, H_{Ar}, J = 7.2 Hz), 7.42 d. d (1H, H_{Ar}, J = 0.8, J = 7.2 Hz), 7.80–7.83 m, 7.93–7.96 m, 7.99–8.10 m (4H, H_{Pht}). ^{13}C NMR spectrum, δ, ppm: 18.12 (CH_3), 19.76, 20.81, 30.53, 32.72 ($C^{3''}$, $C^{4''}$, $C^{5''}$, $C^{6''}$), 57.17 ($C^{2''}$), 74.90 ($C^{1''}$), 123.82, 124.03, 127.45, 128.91, 130.77, 134.75 (C^4, C^5, C^6, C^7, $C^{3'}$, $C^{4'}$, $C^{5'}$), 131.97, 132.06, 138.43, 144.51 (C^{3a}, C^{7a}, $C^{1'}$, $C^{2'}$, $C^{6'}$), 168.32, 169.41 (C^1, C^3). Mass spectrum, *m/z* (I_{rel}, %): 316 (60) $[M - Br_2 + H]^+$, 334 (100) $[M - Br_2 + H_2O + H]^+$.

2-[2-(6-Bromo-1-cyclohexen-1-yl)phenyl]-1*H*-isoindole-1,3(2*H*)-dione (9a). 0.32 g (0.11 mL, 2.0 mmol) of Br_2 in 5 mL of CH_2Cl_2 was slowly added to a suspension of 0.606 g (2.0 mmol) of compound **1a** and 0.98 g (12 mmol) $NaHCO_3$ in 10 mL CH_2Cl_2 under vigorous stirring. The reaction mixture was stirred until the solution became colorless, diluted with 30 mL of H_2O, and extracted with 70 mL of CH_2Cl_2. The organic phase was dried over Na_2SO_4. The solvent was evaporated under reduced pressure, the residue was chromatographed through a layer of silica gel (5 g, eluent: $CHCl_3$). Yield 0.69 g (90%), white amorphous powder, R_f 0.33 ($CHCl_3$). ^1H NMR spectrum, δ, ppm: 1.51–2.19 m (3×2H, $3CH_2$), 4.72 br. s (1H, $H^{6''}$), 5.62 d. d (1H, $H^{2''}$), 7.12 d. d (1H, H_{Ar}, J = 1.3, J = 7.6 Hz), 7.32–7.38 m (1H, H_{Ar}), 7.62 d. d (1H, H_{Ar}, J = 1.6, J = 7.6 Hz), 7.68 d. d (2H, H_{Ar}, J = 3.0, J = 5.0 Hz), 7.82 d. d (2H, H_{Ar}, J = 3.0, J = 5.0 Hz). ^{13}C NMR spectrum, δ_C, ppm: 16.70, 25.18, 33.01 ($C^{3''}$, $C^{4''}$, $C^{5''}$), 50.81 ($C^{6''}$), 123.43, 123.60, 128.26, 129.02, 129.10, 130.73, 131.90, 134.04, 134.08 (C^4, C^5, C^6, C^7, $C^{2'}$, $C^{3'}$, $C^{4'}$, $C^{5'}$, $C^{2''}$), 129.63, 131.96, 135.93, 141.03 (C^{3a}, C^{7a}, $C^{1'}$, $C^{2'}$, $C^{1''}$, $C^{6'}$), 166.93, 167.13 (C^1, C^3).

2-[2-(6-Bromo-1-cyclohexen-1-yl]-6-methylphenyl]-1*H*-isoindole-1,3(2*H*)-dione (9b) was obtained similarly from 0.634 g (2.0 mmol) of compound **2b** and 0.32 g (2.0 mmol) Br_2 in the presence of 0.98 g (12 mmol) of $NaHCO_3$. 0.55 g (70%) of purified sample was obtained via column chromatography on silica gel (10 g, eluent: benzene), mp 145–155°C (C_6H_6), R_f 0.34 ($CHCl_3$). IR spectrum, ν, cm^{-1}: 719, 1380, 1461, 1699. ^1H NMR spectrum, δ, ppm: 1.54–1.61 m (2H, CH_2), 1.86–2.16 m (2×2H, $2CH_2$), 2.18 s (3H, CH_3), 4.75 br. s (1H, $H^{6''}$), 5.71 d. d (1H, $H^{2''}$, J = 2.4, J = 4.6 Hz), 7.29 d (1H, H_{Ar}, J = 7.6 Hz), 7.33–7.39 m (1H, H_{Ar}), 7.45 d (1H, H_{Ar}, J = 7.6 Hz), 7.79–7.82 m (2H, H_{Ar}), 7.91–7.94 m (2H, H_{Ar}). ^{13}C NMR spectrum, δ_C, ppm: 16.72, 25.15, 32.97 ($C^{3''}$, $C^{4''}$, $C^{5''}$), 18.22 (CH_3), 51.29 ($C^{6''}$),

123.63, 123.72, 134.31, 134.37 (C^4, C^5, C^6, C^7), 128.50, 130.03 ($C^{3'}$, $C^{5'}$), 129.18 ($C^{4'}$), 131.81 ($C^{2''}$), 123.77, 128.89, 131.91, 136.31, 137.03, 141.59 (C^{3a}, C^{7a}, $C^{1'}$, $C^{2'}$, $C^{1''}$, $C^{6'}$), 167.07, 167.62 (C^1, C^3). Mass spectrum, *m/z* (I_{rel}, %): 316 (60) $[M - Br + H]^+$, 334 (100) $[M - Br + H_2O + H]^+$.

2-[2-(6-Methoxycyclohex-1-en-1-yl)-6-methylphenyl]-1*H*-isoindole-1,3(2*H*)-dione (10). A solution of 0.08 g (0.2 mmol) of compound **9b** in 3 mL of MeOH was refluxed for 1 h and then kept at room temperature for 24 h. The solvent was evaporated under reduced pressure, and the residue was chromatographed on a column with silica gel (2 g, eluent: $CHCl_3$). Yield 0.06 g (86%), mp 110–114°C, R_f 0.75 ($CHCl_3$). IR spectrum, ν, cm^{-1}: 1699, 1460, 1380, 1148, 886. ^1H NMR spectrum, δ, ppm: 1.20–2.09 m (6H, CH_2), 2.20 s (3H, CH_3), 3.20 s (3H, OCH_3), 3.62 s (1H, $H^{6''}$), 5.65 d. d (1H, $H^{2''}$, J = 1.4, J = 2.9 Hz), 7.24 d (1H, H_{Ar}, J = 7.0 Hz), 7.28–7.37 m (2H, H_{Ar}), 7.74–7.79 m (2H, H_{Pht}), 7.85–7.94 m (2H, H_{Pht}). ^{13}C NMR spectrum, δ_C, ppm: 18.12 (CH_3), 16.60, 25.46, 26.56 ($C^{3''}$, $C^{4''}$, $C^{5''}$), 56.99 (OCH_3), 75.66 ($C^{6''}$), 123.33, 123.55, 127.91, 129.02, 129.34, 130.84, 133.98, 134.05 (C^4, C^5, C^6, C^7, $C^{3'}$, $C^{4'}$, $C^{5'}$, $C^{2''}$), 128.69, 132.08, 135.79, 136.76, 142.77, 144.51 (C^{3a}, C^{7a}, $C^{1'}$, $C^{2'}$, $C^{6'}$, $C^{1''}$), 167.20, 167.46 (C^1, C^3). Mass spectrum, *m/z* (I_{rel}, %): 348 $[M + H]^+$ (10), 316 $[M - CH_3OH + H]^+$ (100).

4-Bromo-2-(1-methoxy-2-bromo-1-cyclohexyl)-aniline (12a). 0.9 g (4 mmol) $CuBr_2$ was added to a solution of 0.35 g (2 mmol) aniline **1a** in 10 mL of MeOH. The reaction mixture was kept at room temperature for 24 h, then it was diluted with 50 mL of H_2O under vigorous stirring, and the product was extracted with 70 ml of CH_2Cl_2. The organic phase was dried over Na_2SO_4, the solvent was evaporated under reduced pressure, the residue was chromatographed on a silica gel column (40 g, eluent: C_6H_6). Yield 0.57 g (79%), R_f 0.66 (C_6H_6). IR spectrum, ν, cm^{-1}: 3360, 3465 (NH_2). ^1H NMR spectrum, δ, ppm: 1.50–2.55 m (8H, CH_2), 3.12 s (3H, OCH_3), 5.18 q (1H, $C^{2'}H$, J = 3.0 Hz), 5.22 br. s (2H, NH_2), 7.10 d (1H, H_{Ar}, J = 2.2), 7.37 d. t (1H, H_{Ar}, J = 2.2, J = 7.6 Hz), 7.52 d (1H, H_{Ar}, J = 7.6 Hz). ^{13}C NMR spectrum, δ_C, ppm: 19.70, 20.4, 24.9, 29.9 ($4CH_2$), 50.6 (OCH_3), 52.9 ($C^{2'}$), 81.2 ($C^{1'}$), 109.3, 127.0, 144.3 (C^1, C^2, C^4), 118.1, 131.1, 132.5 (C^3, C^5, C^6). Found, %: C 42.85; H 4.59; Br 43.75; N 4.28. $C_{13}H_{17}Br_2NO$. Calculated, %: C 43.00; H 4.72; Br 44.01; N 4.41.

2-(1-Methoxy-2-bromo1-cyclohexyl)aniline (13a) was obtained similarly from 0.35 g (2 mmol) of aniline **1a** and 0.45 g (2 mmol) of $CuBr_2$. The product was isolated via silica gel column chromatography. Yield 0.45 g (80%), R_f 0.47 (C_6H_6). IR spectrum, ν, cm^{-1}: 3360, 3465 (NH_2). ^1H NMR spectrum, δ, ppm: 1.50–2.59 m (8H, CH_2), 3.15 s (3H, OCH_3), 5.25 q (1H, $C^{2'}H$, J = 3.0 Hz), 5.30 br. s (2H, NH_2), 7.00–7.60 m (4H, H_{Ar}). ^{13}C NMR spectrum, δ_C, ppm: 19.70, 20.6, 24.7, 30.3 ($4CH_2$), 50.8 (OCH_3), 53.4 ($C^{2'}$), 81.3 ($C^{1'}$), 109.6, 144.0 (C^1, C^2), 118.0, 126.7, 131.3, 132.7 (C^3, C^4, C^5, C^6). Found, %: C 54.82; H 6.19; Br 27.91; N 4.78. $C_{13}H_{18}BrNO$. Calculated, %: C 54.94; H 6.38; Br 28.12; N 4.93.

4-Bromo-2-(1-methoxy-2-bromo-1-cyclopentyl)-6-methylaniline (12b) was obtained similarly from 0.35 g (2 mmol) of aniline **11b** and 0.9 g (4 mmol) of $CuBr_2$. The product was isolated via silica gel column chromatography. Yield 0.61 g (85%), R_f 0.67 (C_6H_6). IR spectrum, ν, cm^{-1}: 3370, 3460 (NH_2). ^1H NMR spectrum, δ, ppm: 1.70–2.05 m (2H, $C^{4'}H_2$), 2.16 s (3H, CH_3), 2.19–2.37 m (2H, $C^{5'}H$, $C^{3'}H$), 2.59 d. t (1H, $C^{5'}H$, J= 10.0, J = 13.8 Hz), 2.68–2.82 m (1H, $C^{3'}H$), 3.09 s (3H, OCH_3), 4.51 br. s (2H, NH_2), 5.08 d. d. d (1H, $H^{2'}$, J = 1.2, J = 1.6, J = 6.3 Hz), 7.13 d (1H, H_{Ar}, J = 2.2,), 7.17 d (1H, H_{Ar}, J = 2.2 Hz). ^{13}C NMR spectrum, δ_C, ppm: 17.50 (CH_3), 19.3, 27.6, 34.8, ($3CH_2$), 51.4 ($C^{2'}$), 54.5 (OCH_3), 92.8 ($C^{1'}$), 106.4, 124.2, 124.4, 143.4 (C^1, C^2, C^4, C^6), 130.1, 132.7 (C^3, C^5). Found, %: C 42.79; H 4.58; Br 43.82; N 3.68. $C_{13}H_{17}Br_2NO$. Calculated, %: C 43.00; H 4.72; Br 44.01; N 3.86.

2-(1-Methoxy-2-bromo-1-cyclopentyl)-6-methyl-aniline (13b) was obtained by further eluting from the chromatography column (cf. the previous experiment). Yield 0.06 g (11%), R_f 0.45 (C_6H_6). IR spectrum, ν, cm^{-1}: 3370, 3460 (NH_2). ^1H NMR spectrum, δ, ppm: 1.70–2.05 m (2H, C^4H_2), 2.14 s (3H, CH_3), 2.15–2.35 m (2H, $C^{5'}H$, $C^{3'}H$), 2.55 d. t (1H, $C^{5'}H$, J = 10.0, J = 13.8 Hz), 2.65–2.78 m (1H, $C^{3'}H$), 3.10 s (3H, OCH_3), 4.45 br. s (2H, NH_2), 5.05 d. d. d (1H, $H^{2'}$, J = 1.2, J = 1.6, J = 6.3 Hz), 7.15–7.39 m (3H, H_{Ar}). ^{13}C NMR spectrum, δ_C, ppm: 17.50 (CH_3), 19.1, 27.3, 34.7 ($3CH_2$), 51.1 ($C^{2'}$), 54.0 (OCH_3), 92.50 ($C^{1'}$), 106.2, 124.3, 143.6 (C^1, C^2, C^6), 124.3, 130.2, 132.7 (C^3, C^4, C^5). Found, %: C 54.75; H 6.34; Br 27.86; N 4.81; $C_{13}H_{18}BrNO$. Calculated, %: C 54.94; H 6.38; Br 28.12; N 4.93.

2-(1-Methoxy-2-bromo-1-cyclohexyl)-4-(1-methyl-but-2-en-1-yl)-6-methylaniline (13c) was obtained via the reaction of 0.69 g (2.7 mmol) of amine **1c** [37] and 1.22 g (5.5 mmol) of $CuBr_2$ in 10 mL of MeOH.

The product was isolated via silica gel column chromatography (25 g, eluent: C_6H_6). Yield 0.79 g (80%), R_f 0.66 (C_6H_6). IR spectrum, ν, cm^{-1}: 3370, 3465 (NH_2). ^1H NMR spectrum, δ, ppm: 1.29 d. d (3H, CH_3, J = 1.0, J = 7.0 Hz), 1.69 d. d (3H, CH_3, J = 1.0, J = 6.2 Hz), 1.50–2.59 m (8H, $4CH_2$), 2.16 s (3H, CH_3), 3.10 s (3H, OCH_3), 3.27 q (1H, $H^{1''}$, J = 7.0 Hz), 4.50 br. s (2H, NH_2), 5.30 d. d (1H, $H^{2'}$, J = 1.2, J = 6.2 Hz), 5.35–5.65 m (2H, HC=CH), 6.75 s (1H, H_{Ar}), 6.85 s (1H, H_{Ar}). ^{13}C NMR spectrum, δ_C, ppm: 17.90, 17.95, 21.37 ($3CH_3$), 19.9, 20.5, 25.2, 30.0 ($4CH_2$), 41.41 ($CH^{1''}$), 50.4 ($C^{2'}$), 54.1 (OCH_3), 81.7 ($C^{1'}$), 122.2, 124.0, 133.7, 141.3 (C^1, C^2, C^4, C^6), 122.8, 126.7, 128.5, 136.9 (C^3, C^5, $C^{2''}$, $C^{3''}$). Found, %: C 62.08; H 7.57; Br 21.54; N 3.72. $C_{19}H_{28}BrNO$. Calculated, %: C 62.29; H 7.70; Br 21.81; N 3.82.

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CONFLICT OF INTEREST

No conflict of interest was declared by authors.

REFERENCES

1. Hurd, C.D. and Jenkins, W.W., *J. Org. Chem*., 1957, vol. 22, no. 11, p. 1418. doi 10.1021/jo01362a029
2. Denmark, S.E. and Chi, H.M., *Synthesis*, 2017, vol. 49, p. 2873. doi 10.1055/s-0036-1589002.
3. Hamada, Y., Kunimune, I., and Hara, O., *Heterocycles*, 2002, vol. 56, nos. 1–2, p. 97. doi 10.3987/COM-01-S(K)46
4. Sharma, P., Kaur, N., Jain, S., and Kishore, D., *J. Curr. Chem. Pharm. Sci*., 2013, vol. 3, no. 1, p. 80.
5. Kessler, A., Coleman, C.M., Charoenying, P., and O'Shea, D.F., *J. Org. Chem*., 2004, vol. 69, no. 23, p. 7836. doi 10.1021/jo048723e
6. Bumagin, N.A. and Luzikova, E.V., *J. Organomet. Chem*., 1997, vol. 532, no. 1–2, p. 271. doi 10.1016/S0022-328X(96)06794-0
7. Gataullin, R.R., *Vest. S.-Peterburg. Gos. Univ*., *Ser. 4*, 2014, no. 1, p. 52.
8. Ogawa, T., Nakamura, T., Araki, T., Yamamoto, K., Shuto, S., and Arisawa, M., *Eur. J. Org. Chem*., 2012, p. 3084. doi 10.1002/ejoc.201200260
9. Nicolaou, K.C., Roecker, A.J., Hughes, R., van Summeren, R., Pfefferkorna, J.A., and Winssinger, N., *Bioorg. Med. Chem*., 2003, vol. 11, no. 3, p. 465. doi 10.1016/S0968-0896(02)00386-3
10. Xu, G., Wei, H., Ren, Y., Yin, J., Wang, A., Zhang, T., *Green Chem.*, 2016, vol. 18, p. 1332. doi 10.1039/c5gc01914a
11. Chainikova, E.M., Pankratyev, E.Yu., Teregulova, A.N., Gataullin, R.R., and Safiullin, R.L., *J. Phys. Chem. (A)*, 2013, vol. 117, no. 13, p. 2728. doi 10.1021/jp401038g
12. Brucelle, F. and Renaud, P., *J. Org. Chem*., 2013, vol. 78, no. 12, p. 6245. doi 10.1021/jo4009904
13. Reding, M.T., Kabaragi, Y., Tokuyama, H., and Fukuyama, T., *Heterocycles*, 2002, vol. 55, nos. 1–2, p. 313. doi 10.3987/COM-01-S(K)42
14. Xu, H.-D., Jia, Z.-H., Xu, K., Zhou, H., and Shen, M.-H., *Org. Lett*., 2015, vol. 17, no. 1, p. 66. doi 10.1021/ol503247t
15. Xiao, Y.-C. and Moberg, C., *Org. Lett*., 2016, vol. 18, no. 2, p. 308. doi 10.1021/acs.orglett.5b03479
16. Kim, J.N., Lee, H.J., Lee, K.Y., and Kim, H.S., *Tetrahedron Lett*., 2001, vol. 42, no. 22, p. 3737. doi 10.1016/S0040-4039(01)00552-4
17. Gataullin, R.R., Kazhanova, T.V., Karachurina, L.T., Il'yasova, L.T., Davydova, V.A., Sapozhnikova, T.A., Zarudii, F.S., and Abdrakhmanov, I.B., *Pharm. Chem. J*., 2001, vol. 35, no. 9, p. 493. doi 10.1023/A:1014094709169
18. Gataullin, R.R., Khaziev, E.V., Khusnutdinov, R.N., Borisov, I.M., and Abdrakhmanov, I.B., *Russ. J. Appl. Chem*., 2001, vol. 74, no. 11, p. 1910. doi 10.1023/A:1014809214971
19. Gudmundsson, K.S., Sebahar, P.R., D'Aurora Richardson, L., Catalano, J.G., Boggs, S.D., Spaltenstein, A., Sethna, P.B., Brown, K.W., Harvey, R., and Romines, K.R., *Bioorg. Med. Chem. Lett*., 2009, vol. 19, no. 13, p. 3489. doi 10.1016/j.bmcl.2009.05.003
20. Morimoto, Y. and Shirahama, H., *Tetrahedron*, 1996, vol. 52, no. 32, p. 10631. doi 10.1016/0040-4020(96)00608-4
21. Ziegler, F.E. and Berlin, M.Y., *Tetrahedron Lett*., 1998, vol. 39, no. 17, p. 2455. doi 10.1016/S0040-4039(98)00286-X
22. Gataullin, R.R., Sotnikov, A.M., Spirikhin, L.V., and Abdrakhmanov, I.B., *Russ. J. Org. Chem*., 2005, vol. 41, no. 5, p. 715. doi 10.1007/s11178-005-0231-x
23. Gataullin, R.R. and Fatykhov, A.A., *Russ. J. Gen. Chem*., 2008, vol. 78, no. 3, p. 442. doi 10.1134/S107036320803018
24. Gataullin, R.R., Sotnikov, A.M., Abdrakhmanov, I.B., and Tolstikov, G.A., *Mendeleev Commun*., 2003, vol. 13, no. 5, p. 235. doi 10.1070/MC2003v013n05ABEH001699
25. Kirillova, I.A., Zalimova M.M., Mulyukova, R.V., Vakhitova, Yu.V., and Gataullin, R.R., *Russ. J. Gen. Chem*., 2018, vol. 88, no. 3, p. 418. doi 10.1134/S1070363218030076

26. Gataullin, R.R., Afon'kin, I.S., Fatykhov, A.A., Spirikhin, L.V., and Abdrakhmanov, I.B., *Russ. J. Org. Chem*., 2001, vol. 37, no. 6, p. 834. doi 10.1023/A:1012413715466
27. Gataullin, R.R., Nasyrov, M.F., Ivanova, E.V., Kabal'nova, N.N., and Abdrakhmanov, I.B., *Russ. J. Org. Chem*., 2002, vol. 38, no. 5, p. 763. doi 10.1023/A:1019696030069
28. Sakhautdinov, I.M., Leont'eva, N.A., Galin, F.Z., and Vafina, G.F., *Russ. J. Org. Chem*., 2008, vol. 44, no. 7, p. 1009. doi 10.1134/S1070428008070117
29. Grinshtein, J. and Vinnits, M., *Khimiya aminokislot i peptidov* (Chemistry of Amino Acids and Peptides), Moscow: Mir, 1965.
30. Rasberry, R.D. and Shimizu, K.D., *Org. Biomol. Chem*., 2009, vol. 7, no. 19, p. 3899. doi 10.1039/B909567E
31. Degenhardt, III, C.F., Lavin, J.M., Smith, M.D., and Shimizu, K.D., *Org. Lett*., 2005, vol. 7, no. 19, p. 4079. doi 10.1021/ol051325t
32. Smits, R.A., Adami, M., Istyastono, E.P., Zuiderveld, O.P., van Dam, C.M.E., de Kanter, F.J.J., Jongejan, A., Coruzzi, G., Leurs, R., and de Esch, I.J.P., *J. Med. Chem*., 2010, vol. 53, no. 6, p. 2390. doi 10.1021/jm901379s
33. Gataullin, R.R., Afon'kin, I.S., Fatykhov, A.A., Spirikhin, L.V., and Abdrakhmanov, I.B., *Russ. Chem. Bull*., 2000, vol. 49, no. 1, p. 122. doi 10.1007/BF02499076
34. Ortgies, S. and Breder, A., *Org. Lett*., 2015, vol. 17, p. 2748. doi 10.1021/acs.orglett.5b01156
35. Li, Y.-L., Li, J., Ma, A.-L., Huang, Y.-N., and Deng, J., *J. Org. Chem*., 2015, vol. 80, no. 8, p. 3841. doi 10.1021/acs.joc.5b00090
36. HyperChem 8.0 Free trial version. www.hyper.com.
37. Gataullin, R.R., Ishberdina, R.R., Sotnikov, A.M., and Abdrakhmanov, I.B., *Russ. J. Appl. Chem*. 2005, vol. 78, no. 3, p. 438. doi 10.1007/s11167-005-0312-1
38. Gataullin, R.R., Afon'kin, I.S., Pavlova, I.V., and Abdrakhmanov, I.B., *Russ. Chem. Bull*., 1999, vol. 48, no. 2, p. 396. doi 10.1007/BF02494577