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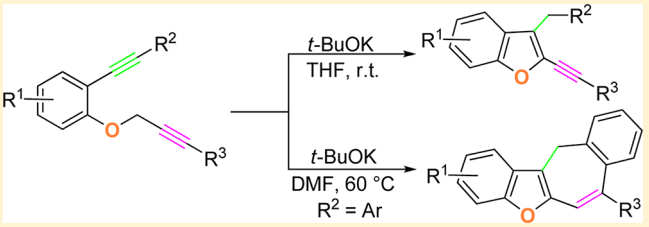
Potassium *tert*-Butoxide Promoted Annulation of 2-Alkynylphenyl Propargyl Ethers: Selective Synthesis of Benzofuran and 12*H*-Benzoannulene Derivatives

Tamiris B. Grimaldi,[†] Davi F. Back,[‡] and Gilson Zeni*[,†]

[†]Laboratório de Síntese, Reatividade, Avaliação Farmacológica e Toxicológica de Organocalcogênios and [‡]Laboratório de Materiais Inorgânicos, CCNE, UFSM, Santa Maria, Rio Grande do Sul, Brazil 97105-900

Supporting Information

ABSTRACT: We present here our results on potassium *tert*-butoxide promoted annulation reactions of 2-alkynylphenyl propargyl ethers to give two different types of heterocycles: 3-benzyl-2-alkynylbenzofurans and 12*H*-benzoannulenbenzo[*b*]-furans. A series of functionalized 2-alkynylphenyl propargyl ethers were efficiently cyclized by potassium *tert*-butoxide to the corresponding products. The optimized reaction conditions tolerated a large variety of functional groups, including electron-rich, electron-poor, and N-heterocyclic substrates. Selective product formation was obtained by controlling the solvent and temperature. When THF was used at room temperature, 3-benzyl-2-alkynylbenzofuran derivatives were exclusively obtained, while the use of DMF at 60 °C gave selectively 12*H*-benzoannulen[*b*]benzofurans.



INTRODUCTION

The annulation reaction, which involves a new carbon−carbon bond formation, represents a powerful methodology in the synthesis of cyclic compounds.[1] Specifically, intermolecular annulations have been widely employed for the transformation of alkynes to the corresponding N,O-heterocycles.[2] The most general and appropriate methodology includes the transition-metal-catalyzed annulation of both terminal and internal alkynes via a nucleophilic attack at the activated triple bond.[3] The other approach involves the activation of carbon−carbon bonds of alkynes with an electrophilic source followed by an intramolecular carbon nucleophilic attack at the activated triple bond to give both carbocycles and heterocycles.[4] The synthesis of heterocyclic compounds by using the base-promoted annulation of alkynes has attracted considerable interest.[5] This synthetic strategy has significant advantages over other methodologies, particularly in the reduction of generation of chemical wastes, reaction time, solvent, and energy, demonstrating the clear economic and environmental benefits. From a synthetic point of view, benzyl alkynyl ethers are often chosen in base-promoted annulation as ideal substrates, because they have an acidic hydrogen between the carbon−heteroatom bond that is adequately stabilized, making it more susceptible to carbanion formation.[6] One of the interesting features of this process is the fact that the initial carbanion formed could result in an intermediate allyl anion with two carbons having nucleophilic character, which could undergo intramolecular cyclization via 5-exo-dig or 6-endo-dig modes,[7] determined by the steric and electronic effects and by the Baldwin rules. Several authors have described the intramolecular cyclization of 2-alkynylphenyl benzoylmethyl ethers as well as 2-allylphenyl benzoylmethyl ethers or 2−3-oxopropenyl propargyl ethers, but the base-promoted cyclization of 2-alkynylphenyl propargyl ethers has not received much attention.[8] In addition, a tandem base-promoted annulation of 2-alkynylphenyl propargyl ethers to prepare a furan-fused tetracycle has not been thoroughly explored. Our aim was to develop conditions for the base-promoted annulation of 2-alkynylphenyl propargyl ethers **1** for the selective synthesis of 3-benzyl-2-alkynylbenzofurans **2** or 12*H*-benzoannulen[*b*]benzofurans **3** (Scheme 1). Tetracyclic furans bearing a fused seven-membered ring are a class of natural or synthetic polycycles that display a range of different biological activities.[9] Members of this family possess antimicrobial,[10] cytotoxic,[11] antiulcer,[12] and anti-inflammatory activities.[13] Although numerous studies for the chemistry and preparation of furan-fused five- and six-membered tetracycles have been reported, the preparation of seven-membered derivatives is limited and generally involves a multistep synthesis.[14] Thus, a one-step synthesis of fused heterocycles containing a seven-membered ring has been a great challenge.

RESULTS AND DISCUSSION

The starting 2-alkynylphenyl propargyl ethers **1** were readily prepared from commercial 2-halophenol derivatives by alkylation with propargyl bromides[15] followed by a Sonogashira cross-coupling reaction with terminal alkynes.[16] After that, our efforts concentrated on determining the reaction parameters, which could affect the annulation reaction. We first began to

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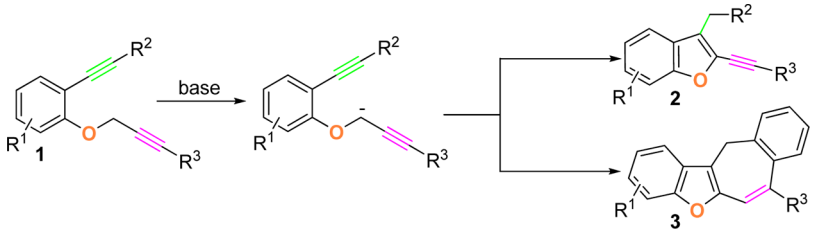
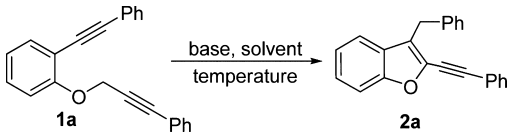
Scheme 1



screen the action of bases, solvents, and temperature in the cyclization of 2-alkynylphenyl propargyl ether **1a**. The reaction carried out with *t*-BuOK (1.5 equiv) as base, in DMF (3 mL) at 90 °C for 1 h under an argon atmosphere, unfortunately failed to give the benzofuran **2a**; instead, the cyclized product **3a** was obtained in 74% yield (Table 1, entry 1). Although the formation of **3a** was encouraging, the absence of **2a** suggests that the combination of higher reaction temperature (90 °C) and the solvent could induce the formation of **3a**. Thus, when the reaction temperature was lowered to 0 °C, the product **2a** was obtained after 8 h in 56% yield with a 24% yield of **3a**, while a reduction in the amount of base afforded exclusively **2a**, although the yield was poor (Table 1, entries 2 and 3). Further screening revealed that other bases such as K_2CO_3, NaH, KOH, Et_3N, Cs_2CO_3, K_3PO_4, and NaOAc, using tetrahydrofuran as solvent, were ineffective in providing the product **2a** (Table 1, entries 4–10). The combination of *t*-BuOK (1.5 equiv) and tetrahydrofuran, at room temperature, had a dramatic effect on the outcome of this cyclization, leading to the desired benzofuran **2a** in 92% yield after 1 h (Table 1, entry 11). The results demonstrated that the loadings of *t*-BuOK also had a fundamental influence on the cyclization reaction. With 1.0 and 1.2 equiv of *t*-BuOK, for instance, no reaction was observed when the temperature and reaction time were changed (Table 1, entries 12–15). It is worth noting that good yields were achieved using 2.0 and 2.5 equiv of *t*-BuOK, but no reaction took place in the presence of a catalytic amount of *t*-BuOK (Table 1, entries 16–18). As can be seen from Table 1, of the solvents screened, dioxane gave results similar to those for THF. For the other solvents, such as ethanol, water, dichloromethane, and acetonitrile, no trace of benzofuran **2a** was obtained (Table 1, entries 19–24). However, when DMSO was used as solvent, in the presence of *t*-BuOK (1.5 equiv), 12*H*-benzoannulene[*b*]benzofuran **3a**, observed in Table 1, entry 1, was obtained exclusively in 85% yield, after 1 h (Table 1, entry 25). This result supports our hypothesis that the temperature and base play a crucial role in the rate and the product distribution of benzofuran **2a** and 12*H*-benzoannulene-[*b*]benzofuran **3a**. To test the effect of dilution on the rate of the reaction, 1 and 5 mL of THF were employed instead of 3 mL and a similar rate of reaction was obtained. On the basis of this investigation, we concluded that the annulation reaction of 2-alkynylphenyl propargyl ether **1a** (0.25 mmol) carried out in the presence of *t*-BuOK (1.5 equiv) in THF (3 mL), for 1 h at room temperature, was the optimal condition to provide the benzofuran **2a**.

Table 1. Effect of Different Reaction Parameters on the Preparation of Benzofuran 2a[a]



entry	base (equiv)	solvent	temp (°C)	yield (%)[b]
1	*t*-BuOK (1.5)	DMF	90	0[e]
2	*t*-BuOK (1.5)	DMF	0	56[d]
3	*t*-BuOK (0.2)	DMF	0	39
4	K_2CO_3 (1.5)	THF	25	0
5	NaH (1.5)	THF	25	0
6	KOH (1.5)	THF	25	0
7	Et_3N (1.5)	THF	25	0
8	Cs_2CO_3 (1.5)	THF	25	0
9	K_3PO_4 (1.5)	THF	25	0
10	NaOAc (1.5)	THF	25	0
11	*t*-BuOK (1.5)	THF	25	92
12	*t*-BuOK (1.0)	THF	25	0
13	*t*-BuOK (1.0)	THF	75	0
14	*t*-BuOK (1.0)	THF	0	0
15	*t*-BuOK (1.2)	THF	25	0
16	*t*-BuOK (0.2)	THF	0	0
17	*t*-BuOK (2.0)	THF	0	86
18	*t*-BuOK (2.5)	THF	0	91
19	*t*-BuOK (1.5)	EtOH	25	0
20	*t*-BuOK (1.5)	H_2O	25	0
21	*t*-BuOK (1.5)	CH_2Cl_2	25	0
22	*t*-BuOK (1.5)	dioxane	25	99
23	*t*-BuOK (1.0)	dioxane	25	0
24	*t*-BuOK (1.5)	CH_3CN	25	0
25	*t*-BuOK (1.5)	DMSO	25	0[e]

[a]The reaction was performed in the presence of **1a** (0.25 mmol) and *t*-BuOK (1.5 equiv) in THF (3 mL) under an argon atmosphere for 1 h at room temperature. [b]Yields were determined by GC analysis. [c]The product **3a** was obtained in 74% yield. [d]The product **3a** was obtained in 24% yield. [e]The product **3a** was obtained in 85% yield.

After the optimization of the reaction conditions a range of 2-alkynylphenyl propargyl ethers **1** were evaluated for direct annulation, and the results are summarized in Table 2. 2-Alkynylphenyl propargyl ethers **1** of diverse structural and electronic nature underwent the cyclization to form 3-benzyl-2-alkynylbenzofurans **2** in good yields, requiring a very short reaction time. At the beginning we studied the effect of the substituent on aryl bonded to the propargyl group. We found out that the reaction proceeded very well when either an electron donor or an electron acceptor group was on the aryl group (Table 2, entries 1–7). In addition, it must be pointed out that it was possible to perform the cyclization with the 2-alkynylphenyl propargyl ether **1h**, which has a hindered 1-naphthyl substituent at the terminal position of the alkyne (Table 2, entry 8). Furthermore, the heteroaryl thiophene, directly bonded to the alkyne, was also a suitable reactant under these cyclization conditions, giving 3-benzyl-2-alkynylbenzofuran **2i** in 87% yield (Table 2, entry 9). The optimized conditions

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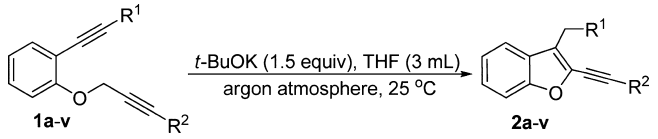
Table 2. Synthesis of 3-Benzyl-2-alkynylbenzofurans 2[a]



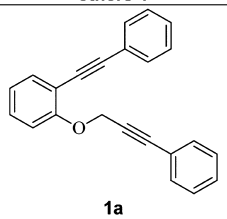
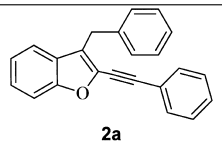
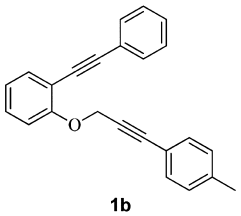
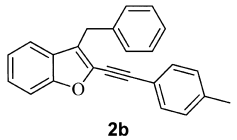
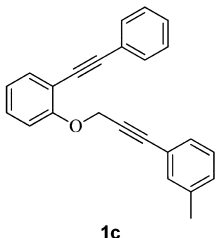
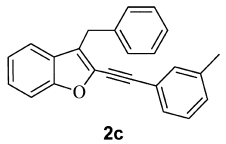
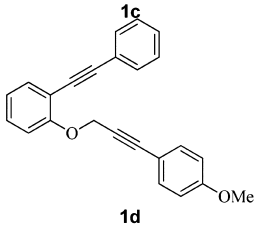
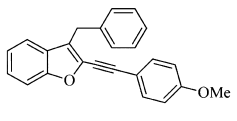
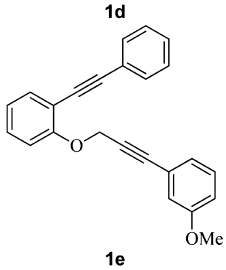
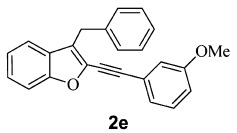
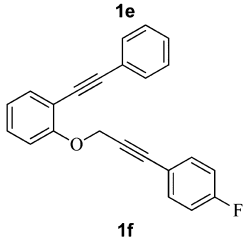
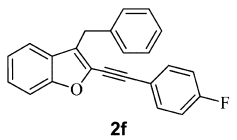
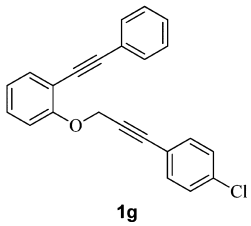
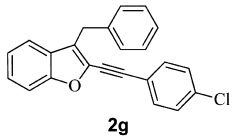
entry	2-alkynylphenyl propargyl ethers 1	products 2	yield (%)/time (min)
1	 **1a**	 **2a**	92/5
2	 **1b**	 **2b**	86/5
3	 **1c**	 **2c**	78/5
4	 **1d**	 **2d**	90/5
5	 **1e**	 **2e**	84/5
6	 **1f**	 **2f**	75/5
7	 **1g**	 **2g**	87/10[b]

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Table 2. continued

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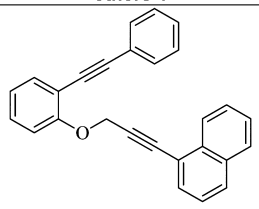
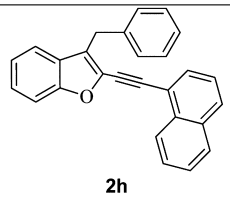
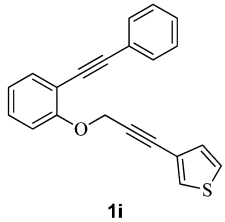
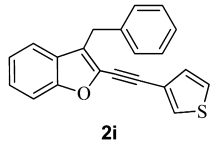
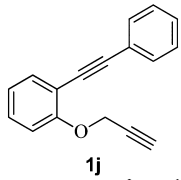
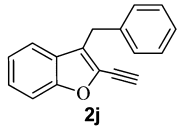
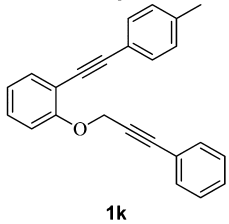
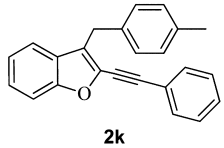
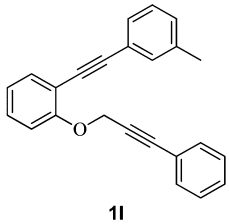
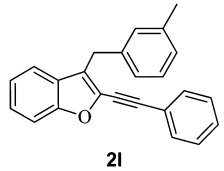
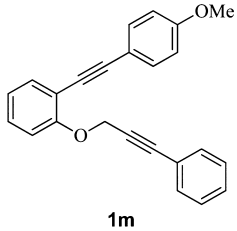
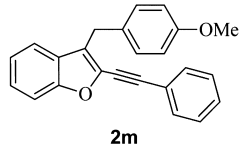
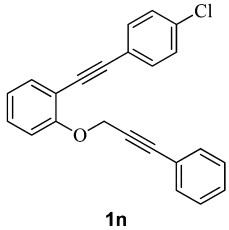
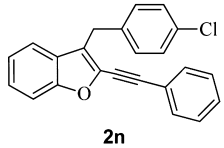
8	 1h	 2h	72/20
9	 1i	 2i	87/20
10	 1j	 2j	67/5[c]
11	 1k	 2k	81/20
12	 1l	 2l	82/5
13	 1m	 2m	90/5
14	 1n	 2n	85/3[b]

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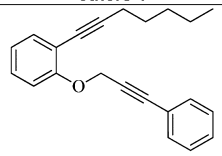
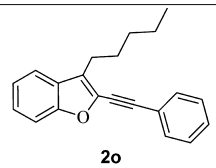
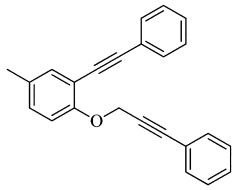
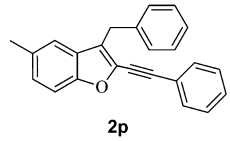
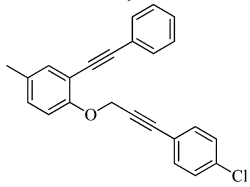
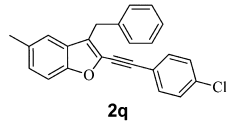
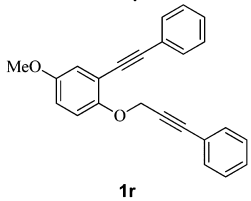
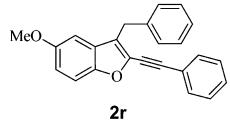
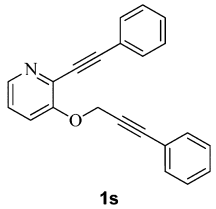
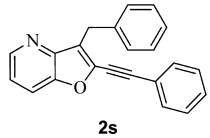
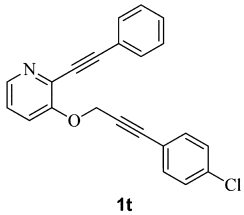
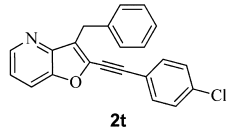
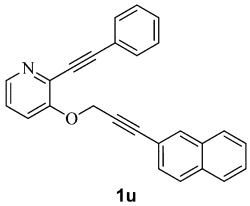
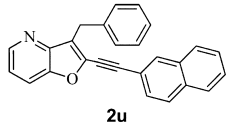
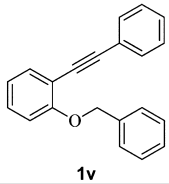
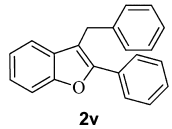
Table 2. continued

entry	2-alkynylphenyl propargyl ethers 1	products 2	yield (%)/time (min)
15	 **1o**	 **2o**	49/5[a]
16	 **1p**	 **2p**	75/5
17	 **1q**	 **2q**	73/3[b]
18	 **1r**	 **2r**	76/5
19	 **1s**	 **2s**	67/5
20	 **1t**	 **2t**	61/5
21	 **1u**	 **2u**	81/5
22	 **1v**	 **2v**	86/5[c]

[a]The reaction was performed in the presence of 2-alkynylphenyl propargyl ethers **1** (0.25 mmol) and *t*-BuOK (1.5 equiv) in THF (3 mL) under an argon atmosphere, at room temperature. [b]The reaction was performed at 0 °C. [c]*t*-BuOK (3.0 equiv) was used. [d]The reaction was performed in the presence of 2-alkynylphenyl propargyl ethers **1** (0.25 mmol) and *t*-BuOK (1.0 equiv) in DMF (3 mL), under an argon atmosphere, at 60 °C.

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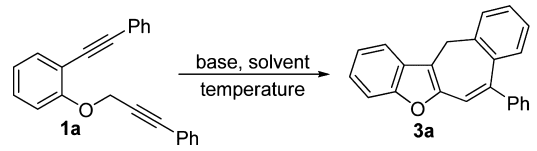
were also efficient for the terminal alkyne **2j** although, due to the acid−base reaction with terminal hydrogen, *t*-BuOK (3.0 equiv) was required (Table 2, entry 10). This result is significant particularly when one considers that there are many ways to transform the resulting terminal alkynes into other substituents.[17] In addition, it has been well described that acetylenic furan derivatives are present in a wide range of compounds that show important biological and pharmaceutical applications.[18] Next, we turned our attention to the influence of substituents directly bonded to the alkyne at the 2-position of the aromatic ring (Table 2, entries 11−15). The yields of the reactions were not sensitive to electronic effects on the aromatic ring. Indeed, electron-withdrawing groups reacted at rates comparable to those for the electron-donating groups (Table 2, entries 11−15). On the other hand, the presence of an alkyl group directly bonded to the triple bond in compound **1o** led to a decrease in the cyclization efficiency, furnishing the corresponding cyclized product **2i** in 49% yield (Table 2, entry 15). In this case, the absence of π bonds in the alkyl chain could result in a decreased reactivity for the nucleophilic attack at the carbon−carbon triple bond. Finally, we studied the cyclization with 2-alkynylphenyl propargyl ethers **1** having different substituents on the aromatic ring that contains the alkynes and propargyl substituents. The *p*-methyl-substituted **1p,q** gave rise to cyclized 3-benzyl-2-alkynylbenzofurans **2p,q** in 75 and 73% yields, respectively (Table 2, entries 16 and 17). A similar result was obtained when *p*-methoxyl-substituted **1r** was utilized in the reaction (Table 2, entry 18). We carried out our study further with pyridine derivatives to determine the influence of an N-heterocycle in the course of this cyclization. For instance, the cyclization reaction of 2-alkynyl-3-propargyl-pyridine with different substituents, such as hydrogen, chlorine, and 1-naphthyl, gave the cyclized products in 61−81% yields (Table 2, entries 19−21). As expected, when the propargyl group was replaced by a benzyl group, the reaction gave the corresponding product in moderate yield, even though *t*-BuOK (3.0 equiv) was necessary (Table 1, entry 22). It appears that a smaller amount of the benzyl carbanion formed when 1.5 equiv of *t*-BuOK was used.

In the process of the reaction condition optimization for the formation of benzofuran **2a**, we observed that 12*H*-benzoannulene[*b*]benzofuran **3a** could be obtained, as the sole product, in 74% and 85% yields depending on the temperature and solvent (Table 1, entries 1 and 25). In light of this result, we focused our efforts on optimizing the reaction conditions to obtain the 12*H*-benzoannulen[*b*]benzofurans **3** directly from 2-alkynylphenyl propargyl ethers **1**, via a one-pot cyclization. In the initial study, the cyclization was performed by using 2-alkynylphenyl propargyl ether **1a** (0.25 mmol) in the presence of DMF (3 mL). Thus, the influence of reaction parameters, such as different bases, temperatures and solvents, was evaluated and the results are summarized in Table 3. For comparison with the efficiency of *t*-BuOK, other bases were tested. When *t*-BuOK was replaced by KOH and NaOH, the yields decreased to 51% and 25%, respectively (Table 3, entries 2 and 3). When the reaction was carried out in the presence of K_3PO_4, no product was detected: just traces of the cyclized product **2a** were obtained (Table 3, entry 4). Other bases, such as Et_3N, Cs_2CO_3, NaOAc, and K_2CO_3, were also tested; however, no product was detected (Table 3, entries 5−8). The solvent remarkably affected the reaction; with EtOH, H_2O, CH_2Cl_2, and dioxane only the starting material **1a** was recovered (Table 3, entries 9−12). When DMSO was used as

Table 3. Effect of Different Reaction Parameters on the Preparation of 12*H*-Benzoanulen[*b*]benzofuran 3a[a]



entry	base (equiv)	solvent	temp (°C)	yield (%)[b]
1	*t*-BuOK (1.5)	DMF	90	74
2	KOH (1.0)	DMF	90	51
3	NaOH (1.0)	DMF	90	25
4	K_3PO_4 (1.0)	DMF	90	0[c]
5	Et_3N (1.0)	DMF	90	0
6	Cs_2CO_3 (1.0)	DMF	90	0
7	NaOAc (1.0)	DMF	90	0
8	K_2CO_3 (1.0)	DMF	90	0
9	*t*-BuOK (1.0)	EtOH	75	0
10	*t*-BuOK (1.0)	H_2O	90	0
11	*t*-BuOK (1.0)	CH_2Cl_2	40	0
12	*t*-BuOK (1.0)	dioxane	90	0
13	*t*-BuOK (1.0)	DMSO	90	27
14	*t*-BuOK (1.0)	CH_3CN	90	0[c]
15	*t*-BuOK (1.5)	THF	25	0[d]
16	*t*-BuOK (1.0)	DMF	25	77
17	*t*-BuOK (1.0)	DMF	60	86
18	*t*-BuOK (1.0)	DMF	120	86
19	*t*-BuOK (0.2)	DMF	90	27[e]
20	*t*-BuOK (1.1)	DMF	60	70
21	*t*-BuOK (1.0)	DMF	90	80
22	*t*-BuOK (2.0)	DMF	90	74
23	*t*-BuOK (2.5)	DMF	90	70

[a]The reaction was performed in the presence of **1a** (0.25 mmol) and *t*-BuOK (1.0 equiv) in DMF (3 mL), under an Ar atmosphere for 1 h at 60 °C. [b]Yields were determined by GC analysis. [c]The product **2a** was obtained in 5% yield. [d]The product **2a** was obtained in 92% yield. [e]The product **2a** was also obtained in 55% yield.

solvent, no further improvement in yield was achieved. In a reaction in which the solvent DMF was replaced by DMSO, the product **3a** was obtained in poor yield, while the use of CH_3CN and a THF/DMF mixture afforded **2a** as the sole product (Table 3, entries 13−15). Reactions at room temperature gave results comparable to those at 90 °C; yields improved to 86% by running the reaction at 60 and 120 °C (Table 3, entries 16−18). Further screening revealed that a change of the amount of *t*-BuOK from 1.1 to 2.5 equiv showed similar efficiency (Table 3, entries 20−23). However, the reaction using 20 mol % of *t*-BuOK gave a mixture of products **3a** and **2a** in 27% and 55% yields, respectively (Table 3, entry 19).

As can be seen from Table 3, the screened reaction parameters revealed that the optimum conditions for the 12*H*-benzoannulene[*b*]benzofuran **3** formation involved stirring the corresponding 2-alkynylphenyl propargyl ethers **1** in DMF (3 mL) with 1.0 equiv of *t*-BuOK for 1 h at 60 °C. These optimized reaction conditions were then applied to other 2-alkynylphenyl propargyl ethers **1a−y**, and the results are given in Table 4. The application of these conditions to 2-alkynylphenyl propargyl ethers bearing hydrogen or electron-donating substituents at the aryl group directly bonded to the alkyne of the propargylic function gave the desired 12*H*-benzoannulene[*b*]benzofurans **3a−e** in 61−91% yields (Table 4, entries 1−6). Similar results were obtained when this aryl

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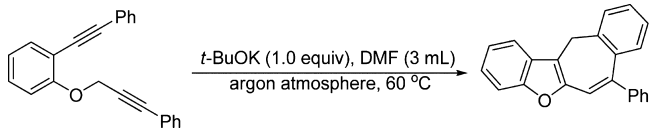
Table 4. Synthesis of 12*H*-Benzoanulen[*b*]benzofurans 3[a]



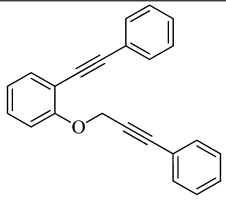
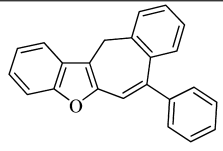
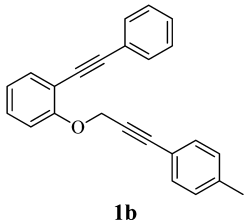
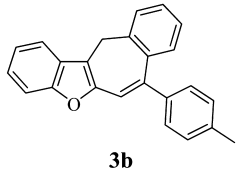
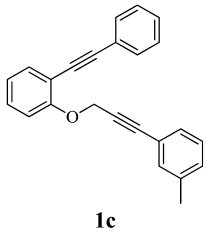
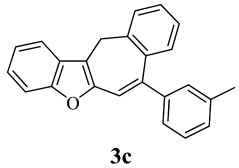
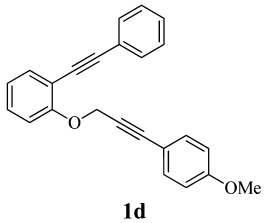
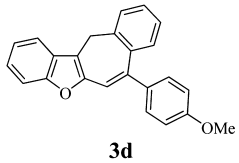
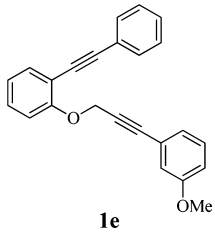
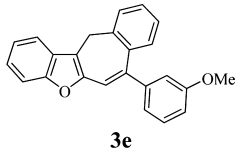
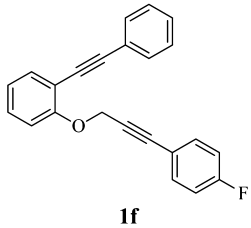
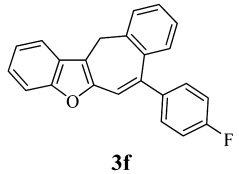
entry	2-alkynylphenyl propargyl ether 1	product 3	yield (%)/time (min)
1	 **1a**	 **3a**	77/5
2	 **1b**	 **3b**	61/60
3	 **1c**	 **3c**	81/5
4	 **1d**	 **3d**	72/60
5	 **1e**	 **3e**	91/5
6	 **1f**	 **3f**	72/60

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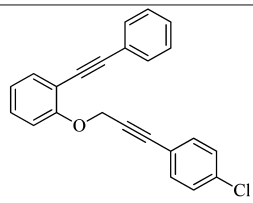
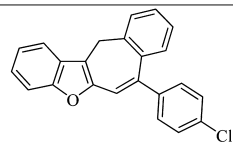
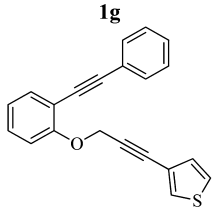
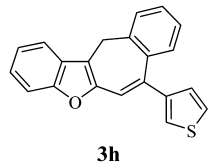
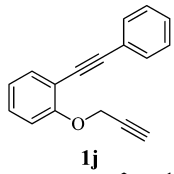
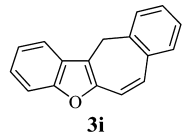
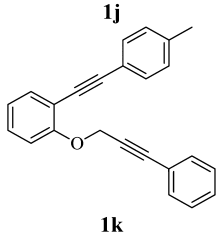
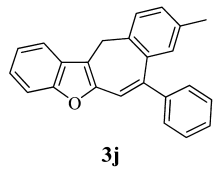
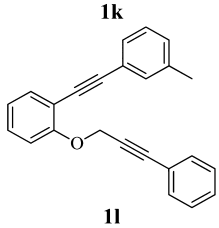
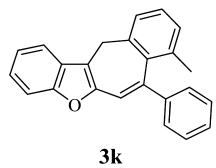
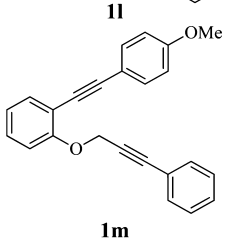
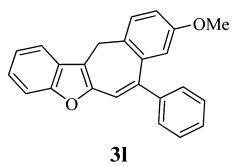
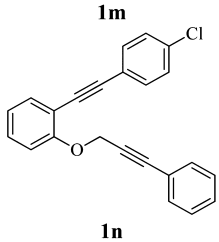
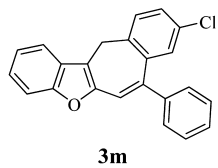
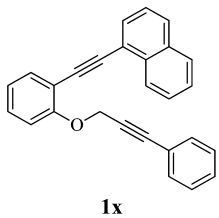
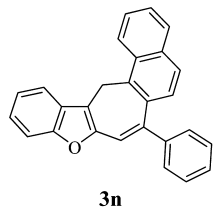
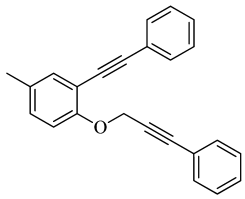
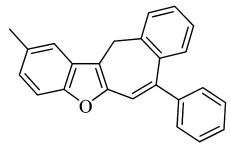
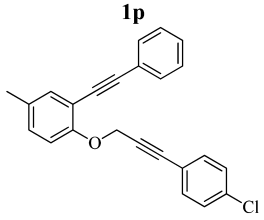
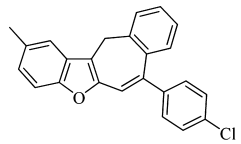
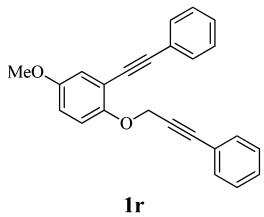
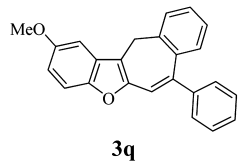
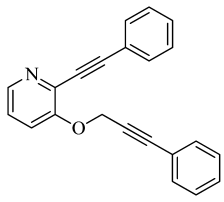
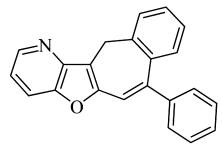
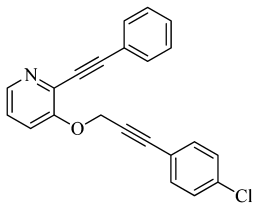
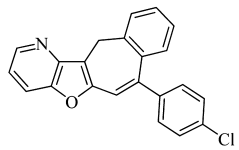
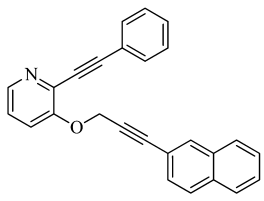
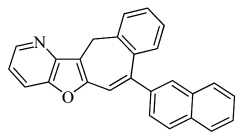
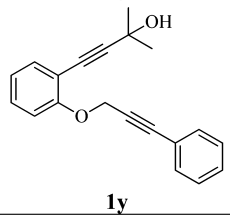
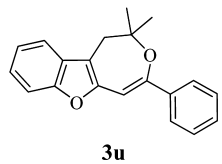
Table 4. continued

entry	2-alkynylphenyl propargyl ether 1	product 3	yield (%)/time (min)
7	 **1g**	 **3g**	76/60
8	 **1i**	 **3h**	78/20
9	 **1j**	 **3i**	29/5
10	 **1k**	 **3j**	70/30
11	 **1l**	 **3k**	62/5
12	 **1m**	 **3l**	84/5
13	 **1n**	 **3m**	79/5
14	 **1x**	 **3n**	82/5

dx.doi.org/10.1021/jo4020062 | J. Org. Chem. 2013, 78, 11017−11031

Table 4. continued

entry	2-alkynylphenyl propargyl ether 1	product 3	yield (%)/time (min)
15	 **1p**	 **3o**	70/60
16	 **1q**	 **3p**	50/5
17	 **1r**	 **3q**	74/5
18	 **1s**	 **3r**	58/5
19	 **1t**	 **3s**	56/5
20	 **1u**	 **3t**	58/5
21	 **1y**	 **3u**	46/5[b]

[a]The reaction was performed in the presence of (2-alkynylphenyl) propargyl ether **1** (0.25 mmol) and *t*-BuOK (1.0 equiv) in DMF (3 mL), under an argon atmosphere at 60 °C . [b]*t*-BuOK (2.0 equiv) was used.

group was substituted by electron-withdrawing substituents (Table 4, entries 6 and 7). When the propargylic function was substituted by a 2-thienyl group, the expected product **3h** was obtained in 78% yield (Table 4, entry 8). Thienyl azulene derivatives have a great number of applications in the semiconductor field, and they have been described as hole-

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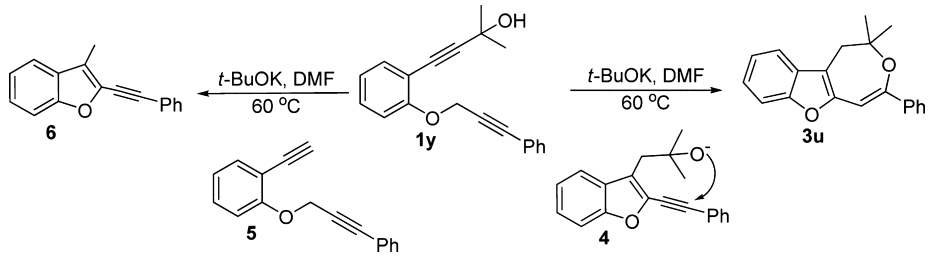
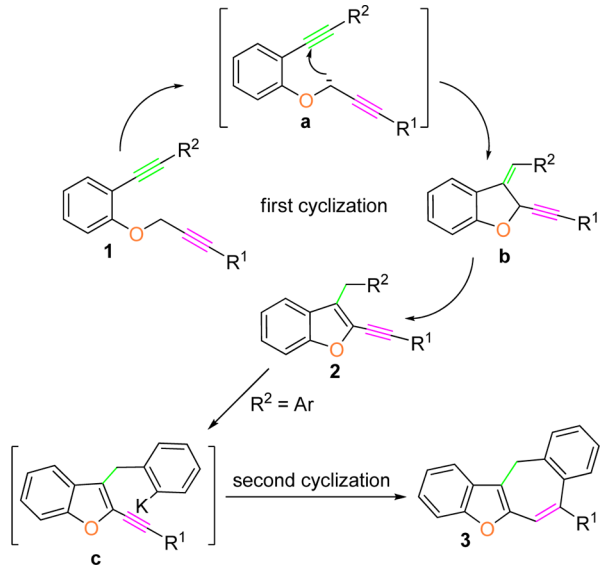
Scheme 2



injecting materials in organic light-emitting devices.[19] The treatment of 2-alkynylphenyl propargyl ether **1j**, which has a terminal alkyne, under the standard optimized conditions, led to the benzoannulene-7-benzofuran **3i** in a yield of only 29% (Table 4, entry 9). However, all of the attempts to improve this reaction yield failed and resulted in undesirable decomposition of the starting material. The additional acidic hydrogen on terminal alkynes most probably contributed to the limited success of this cyclization, even though an excess of base was used. We also studied the introduction of electron-rich and electron-donating groups in the aromatic ring directly bonded to the alkyne at the 2-position. *p*-Me, *p*-OMe, and *p*-Cl were suitable groups for the cyclization process, giving good yields (Table 4, entries 10−13). However, the yield decreased when an *m*-methyl-substituted aryl group was used in this alkyne (Table 4, entry 11). This result shows that the sterically hindered meta aryl position has a significant effect on the reaction yield, at least in the second cyclization step. On the other hand, the electronic effect of the methyl group highly influenced the regioselectivity obtained during the course of this second cyclization. We also examined cyclizations of starting materials having substituents on the central aromatic ring. The aromatic ring tolerated methyl and methoxyl groups at the para position. Although additional reaction time was required for the methyl substituent, the benzoannulene-7-benzofurans **3o−q** were obtained in moderate to good yields (Table 4, entries 15−17). We then turned our attention to the cyclization of heteroaromatic substrates. The cyclization of pyridine derivatives **1s−u**, with different substitutions in the structure, gave in all cases the furo[3,2-*b*]pyridine derivatives **3r−t** in moderate yields (Table 4, entries 18−20). Particularly interestingly, with the substrate **1y**, which has a dimethylcarbinol instead of an aromatic group, the oxygen atom attacked the carbon−carbon triple bond, giving a mixture of the hydrooxepine derivative **3u** and 3-methylbenzofuran **6** in 46% and 24% yields, respectively (Table 4, entry 21). We reasoned that in this case the acidic hydrogen in the hydroxyl group was also effectively removed by *t*-BuOK to generate the nucleophilic alkoxide anion **4**, which attacks the carbon−carbon triple bond, giving the product **3u**. The formation of the 3-methylbenzofuran derivative **6** can be explained by an intramolecular nucleophilic attack of the carbanion on the carbon−carbon triple bond of terminal alkyne **5**, which is formed in situ via a retro-Favorskii reaction[20] (Scheme 2). This result is significant, since a very simple substrate became a versatile precursor for the preparation of an important family of polycyclic active compounds[21] by a one-step cyclization.

The benzofurans **2** and 12*H*-benzoannulene[*b*]benzofurans **3** were identified by their NMR data, and the structures were confirmed by single-crystal X-ray diffraction (Figure 1, Supporting Information). In this context, our cyclization methodology was shown to be regioselective, providing the desired benzofuran **2** via an intramolecular 5-exo-dig mode as the unique regioisomer, while the 12*H*-benzoannulen[*b*]-benzofuran **3** was formed exclusively via a 7-endo-dig mode. The formation of a six-membered ring via the intramolecular 6-endo-dig mode, in the first cyclization, or a six-membered ring via a 6-exo-dig process, in the second cyclization, was not observed in any case. On the basis of these results, we propose the reaction mechanism for potassium *tert*-butoxide annulation of 2-alkynylphenyl propargyl ethers illustrated in Scheme 3.

Scheme 3



The formation of benzofuran derivatives **2** could involve the abstraction of a proton from **1** by *t*-BuOK, generating the carbanion **a**. Intramolecular nucleophilic attack of carbanion **a** at the carbon−carbon triple bond gives intermediate **b**, via an intramolecular 5-exo-dig mode. The isomerization of **b** gives the benzofuran product **2** (Scheme 3). Regarding the possibility of forming a five-membered versus a six-membered ring, it is important to point out that the unique regioisomers obtained during the course of this cyclization were the five-membered benzofuran derivatives. This high regioselectivity can be explained by the Baldwin rule, in which the cyclization of susbtrate, with these interatomic distances, goes on via 5-exo-dig over 6-endo closure.[22] In addition, when 2-alkynylphenyl propargyl ethers **1** reacted with *t*-BuOK in DMF at 60 °C, the product **3** were obtained as a single product. In addition, when isolated **2a** was heated in DMF at 60 °C, in the absence of *t*-BuOK, no cyclized **3a** was obtained, while the reaction of isolated **2a** with *t*-BuOK (1 equiv) in DMF at 60 °C gave the product **3a** in 80% yield. These results suggested that products **3** could be formed by passing through a second cyclization of

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the benzofuran **2** via a carbometalation of the triple bond with the *o*-arylpotassium intermediate **c**.[23] Thus, in this second cyclization the 7-endo-dig mode was preferred over the 6-exo-dig mode, although both processes are acceptable according to the Baldwin rule.[24] It is reasonable to assume that the influence of steric and electronic factors over the competitive cyclization modes is involved.[25]

CONCLUSION

In conclusion, we have explored a base-promoted annulation of 2-alkynylphenyl propargyl ethers for the selective synthesis of 3-benzyl-2-alkynylbenzofurans or 12*H*-benzoannulene[*b*]-benzofurans. The essential role of solvent and temperature for the selectivity in the cyclization was described. In this regard, THF at room temperature gave 3-benzyl-2-alkynylbenzofurans, while the use of DMF at 60 °C gave 12*H*-benzoannulene[*b*]benzofurans. The method tolerated the presence of neutral, electron-donating, and electron-withdrawing groups and N-heterocycles in any part of the substrates. More importantly, this methodology required only one synthetic step to prepare conjugated polycyclic compounds. The 3-benzyl-2-alkynylbenzofurans and 12*H*-benzoannulene[*b*]benzofurans were identified by their NMR data, and the structures were confirmed by single-crystal X-ray diffraction. In this context, our cyclization methodology was shown to be regioselective, providing the desired benzofurans via an intramolecular 5-exo-dig mode as the unique regioisomers, while 12*H*-benzoannulene[*b*]benzofurans were formed exclusively via the 7-endo-dig mode.

EXPERIMENTAL SECTION

General Procedure for the Synthesis of 2-Alkynylphenyl Propargyl Ethers 1.[26,27] To a solution of bis(triphenylphosphine)-palladium(II) dichloride (0.5 mmol) and copper(I) iodide (1 mmol) in dry toluene (50 mL) were added 2-iodophenol (10 mmol), ethynylbenzene (15 mmol), and diisopropylamine (10 mmol). The resulting solution was stirred at room temperature under an argon atmosphere for 2 h. The residue was dissolved in ethyl acetate. and the solution was washed with saturated NH_4Cl, dried ($MgSO_4$), and concentrated in vacuo. The residue was purified by column chromatography over silica gel (hexane/ethyl acetate 98/2) to provide 2-(phenylethynyl)phenols.

To a solution of 2-(phenylethynyl)phenol (7 mmol) in dry acetonitrile (20 mL) was added propargyl bromide (8.75 mmol) followed by anhydrous K_2CO_3 (35 mmol). The reaction mixture was refluxed under an argon atmosphere for 4 h. The mixture was cooled to room temperature and dissolved in ethyl acetate, and the solution was washed with saturated NH_4Cl, dried ($MgSO_4$), and concentrated in vacuo. The residue was purified by column chromatography over silica gel (hexane/ethyl acetate 99/1) to provide 2-alkynylphenyl propargyl ethers **1**.

General Procedure for the Synthesis of Benzofurans 2. To a solution of 2-alkynylphenyl propargyl ether **1** (0.25 mmol) in dry THF (3 mL) was added *t*-BuOK (0.375 mmol). The resulting solution was stirred at room temperature under an argon atmosphere until complete consumption of the starting material. The progress of the reaction was monitored by TLC. The residue was dissolved in ethyl acetate, and the solution was washed with saturated NH_4Cl, dried ($MgSO_4$), and concentrated in vacuo. The residue was purified by column chromatography over silica gel to provide benzofurans **2.** Column chromatography was carried out using hexane as eluent except for **2d,e,m**, for which hexane/ethyl acetate (99/1) was used as eluent, and **2s−u**, for which hexane/ethyl acetate (97/3) was used as eluent.

*3-Benzyl-2-(phenylethynyl)benzofuran (**2a**).* Obtained as a white solid. Yield: 0.071 g (92%); mp 129.5−132.0 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.54−7.51 (m, 2H), 7.41 (d, J = 8.2 Hz, 1H), 7.32−7.30 (m, 6H), 7.25 (t, J = 7.7 Hz, 3H), 7.16 (t, J = 7.2 Hz, 1H), 7.11 (t, J = 7.1 Hz, 1H), 4.16 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.8, 139.1, 136.5, 131.6, 129.0, 128.6, 128.6, 128.5, 128.0, 126.5, 125.7, 124.3, 123.0, 122.1, 120.2, 111.3, 97.7, 79.2, 30.7. MS (EI, 70 eV; m/z (relative intensity)): 309 [M + 1, (24)], 308 (100), 307 (54), 292 (6), 276 (11), 231 (58), 202 (23), 153 (4), 138 (11), 91 (6). Anal. Calcd for $C_{23}H_{16}O$: C, 89.58; H, 5.23. Found: C, 89.66; H, 5.30.

*3-Benzyl-2-(p-tolylethynyl)benzofuran (**2b**).* Obtained as a white solid. Yield: 0.069 g (86%); mp 126.0−128.2 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.43 (t, J = 8.1 Hz, 3H), 7.31 (d, J = 7.7 Hz, 3H), 7.29−7.24 (m, 3H), 7.20−7.11 (m, 4H), 4.16 (s, 2H), 2.35 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.7, 139.3, 139.1, 136.7, 131.5, 129.2, 128.6, 128.5, 128.0, 126.4, 125.5, 123.9, 122.9, 120.1, 119.1, 111.2, 97.9, 78.6, 30.7, 21.5. MS (EI, 70 eV; m/z (relative intensity)): 323 [M + 1, (25)], 322 (100), 321 (40), 307 (23), 305 (18), 245 (24), 231 (30), 202 (23), 153 (27), 139 (15), 138 (20), 91 (12). Anal. Calcd for $C_{24}H_{18}O$: C, 89.41; H, 5.63. Found: C, 89.63; H, 5.72.

*3-Benzyl-2-(m-tolylethynyl)benzofuran (**2c**).* Obtained as a pallid yellow solid. Yield: 0.063 g (78%); mp 119.6−121.0 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.42 (d, J = 8.3 Hz, 1H), 7.36−7.31 (m, 5H), 7.28−7.11 (m, 7H), 4.16 (s, 2H), 2.33 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.8, 139.1, 138.2, 136.6, 132.2, 130.0, 128.7, 128.6, 128.6, 128.4, 128.0, 126.4, 125.6, 124.2, 122.9, 121.9, 120.2, 111.3, 97.9, 78.9, 30.7, 21.2. MS (EI, 70 eV; m/z (relative intensity)): 323 [M + 1, (27)], 322 (100), 321 (43), 307 (24), 245 (18), 231 (31), 202 (18), 153 (14), 138 (13), 91 (14). Anal. Calcd for $C_{24}H_{18}O$: C, 89.41; H, 5.63. Found: C, 89.60; H, 5.69.

*3-Benzyl-2-((4-methoxyphenyl)ethynyl)benzofuran (**2d**).* Obtained as a white solid. Yield: 0.076 g (90%); mp 116.2−118.6 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.48 (d, J = 8.9 Hz, 2H), 7.41 (d, J = 8.2 Hz, 1H), 7.31 (d, J = 7.3 Hz, 3H), 7.26 (t, J = 7.3 Hz, 3H), 7.20−7.15 (m, 1H), 7.13 (t, J = 7.2 Hz, 1H), 6.87 (d, J = 8.9 Hz, 2H), 4.16 (s, 2H), 3.79 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 160.3, 154.7, 139.2, 136.8, 133.2, 128.6, 128.5, 128.1, 126.4, 125.4, 123.5, 122.8, 120.1, 114.2, 114.2, 111.2, 97.7, 78.0, 55.3, 30.7. MS (EI, 70 eV; m/z (relative intensity)): 339 [M + 1, (26)], 338 (100), 337 (26), 323 (18), 293 (15), 261 (14), 231 (16), 189 (23), 176 (14), 132 (18). HRMS: calcd for $C_{24}H_{18}O_2$ (M + Na^+) 361.1199, found 361.1211.

*3-Benzyl-2-((3-methoxyphenyl)ethynyl)benzofuran (**2e**).* Obtained as a pallid yellow solid. Yield: 0.071 g (84%); mp 61.9−63.0 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.40 (d, J = 8.2 Hz, 1H), 7.33 (d, J = 8.2 Hz, 3H), 7.29−7.22 (m, 4H), 7.18 (d, J = 7.1 Hz, 1H), 7.15−7.11 (m, 2H), 7.06 (s, 1H), 6.91 (dd, J = 8.3 Hz, J = 2.5 Hz, 1H), 4.17 (s, 2H), 3.78 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 159.5, 154.8, 139.0, 136.4, 129.6, 128.6, 128.6, 128.0, 126.5, 125.7, 124.4, 124.2, 123.1, 123.0, 120.2, 116.3, 115.8, 111.3, 97.6, 79.0, 55.3, 30.7. MS (EI, 70 eV; m/z (relative intensity)): 339 [M + 1, (25)], 338 (100), 337 (28), 305 (15), 261 (16), 231 (28), 189 (18), 138 (13), 91 (13). Anal. Calcd for $C_{24}H_{18}O_2$: C, 85.18; H, 5.36. Found: C, 85.25; H, 5.42.

*3-Benzyl-2-((4-fluorophenyl)ethynyl)benzofuran (**2f**).* Obtained as a white solid. Yield: 0.061 g (75%); mp 92.6−94.9 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.58−7.54 (m, 2H), 7.46 (d, J = 8.3 Hz, 1H), 7.39−7.30 (m, 6H), 7.26−7.24 (m, 1H), 7.19 (t, J = 7.9 Hz, 1H), 7.09 (t, J = 8.7 Hz, 2H), 4.21 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.9 (d, ^1J = 251.1 Hz), 154.8, 139.0, 136.6, 133.6 (d, ^3J = 8.6 Hz), 128.6, 128.5, 127.9, 126.4, 125.7, 124.3, 123.0, 120.2, 118.2 (d, ^4J = 3.6 Hz), 115.8 (d, ^2J = 22.4 Hz), 111.3, 96.5, 78.9, 30.6. MS (EI, 70 eV; m/z (relative intensity)): 327 [M + 1, (25)], 326 (100), 325 (57), 249 (29), 231 (41), 220 (24), 147 (23), 138 (14), 91 (20). HRMS: calcd for $C_{23}H_{15}FO$ (M + Na^+) 349.0999, found 349.1009.

*3-Benzyl-2-((4-chlorophenyl)ethynyl)benzofuran (**2g**).* Obtained as a pallid yellow solid. Yield: 0.074 g (87%); mp 112.2−114.3 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.44−7.40 (m, 3H), 7.31−7.26 (m, 8H), 7.20−7.12 (m, 2H), 4.15 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.8, 138.9, 136.2, 135.2, 132.8, 128.9, 128.6, 128.6, 127.9, 126.5, 125.8, 124.7, 123.0, 120.6, 120.3, 111.3, 96.5, 80.2, 30.7. MS (EI, 70 eV; m/z (relative intensity)): 334 [M + 1, (36)], 343 (39), 342 (100), 341 (45), 307 (32), 305 (36), 276 (22), 265 (23), 231 (51), 202 (27),

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153 (31), 138 (36). HRMS: calcd for $C_{23}H_{15}ClO$ (M + Na^+) 365.0704, found 365.0725.

*3-Benzyl-2-(naphthalen-1-ylethynyl)benzofuran (**2h**).* Obtained as a pallid brown solid. Yield: 0.064 g (72%); mp 84.9−86.2 °C. ^1H NMR ($CDCl_3$, 400 MHz): δ 8.37 (d, J = 8.1 Hz, 1H), 7.82 (d, J = 8.1 Hz, 2H), 7.76 (d, J = 7.1 Hz, 1H), 7.57−7.41 (m, 4H), 7.38 (d, J = 7.2 Hz, 3H), 7.32−7.25 (m, 3H), 7.21−7.14 (m, 2H), 4.26 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.9, 139.1, 136.7, 133.2, 133.0, 130.8, 129.6, 128.6, 128.4, 128.1, 127.2, 126.7, 126.5, 126.1, 125.8, 125.3, 124.5, 123.0, 120.3, 119.7, 111.4, 96.1, 84.0, 30.8. MS (EI, 70 eV; m/z (relative intensity)): 359 [M + 1, (38)], 358 (100), 357 (50), 342 (15), 281 (22), 252 (21), 231 (18), 207 (19), 178 (17), 163 (20), 150 (17). Anal. Calcd for $C_{27}H_{18}O$: C, 90.47; H, 5.06. Found: C, 90.59; H, 5.10.

*3-Benzyl-2-(thiophen-3-ylethynyl)benzofuran (**2i**).* Obtained as a pallid yellow solid. Yield: 0.068 g (87%); mp 133.0−135.5 °C. ^1H NMR ($CDCl_3$, 400 MHz): δ 7.55 (d, J = 2.3 Hz, 1H), 7.42 (d, J = 8.3 Hz, 1H), 7.33−7.24 (m, 7H), 7.20−7.16 (m, 2H), 7.13 (t, J = 7.3 Hz, 1H), 4.15 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.8, 139.0, 136.5, 129.8, 129.7, 128.6, 128.5, 128.0, 126.4, 125.7, 125.6, 124.1, 122.9, 121.2, 120.2, 111.2, 92.8, 78.7, 30.6. MS (EI, 70 eV; m/z (relative intensity)): 314 (64), 281 (41), 253 (20), 237 (20), 207 (100), 191 (21), 133 (23), 96 (19), 73 (43). HRMS: calcd for $C_{21}H_{14}OS$ (M + H^+) 315.0838, found 315.0856.

*3-Benzyl-2-ethynylbenzofuran (**2j**).* Obtained as a pallid yellow solid. Yield: 0.034 g (59%); mp 82.0−83.3 °C. ^1H NMR ($CDCl_3$, 400 MHz): δ 7.40 (d, J = 8.2 Hz, 1H), 7.32−7.23 (m, 6H), 7.21−7.16 (m, 1H), 7.13 (t, J = 7.4 Hz, 1H), 4.12 (s, 2H), 3.61 (s, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.6, 138.8, 135.4, 128.5, 127.5, 126.4, 125.9, 125.5, 123.0, 120.4, 111.4, 85.7, 73.7, 30.4. MS (EI, 70 eV; m/z (relative intensity)): 233 [M + 1, (16)], 232 (94), 231 (100), 202 (48), 176 (10), 155 (41), 126 (10), 101 (20), 88 (9). HRMS: calcd for $C_{17}H_{12}O$ (M + Na^+) 255.0780, found 255.0791.

*3-(4-Methylbenzyl)-2-(phenylethynyl)benzofuran (**2k**).* Obtained as a white solid. Yield: 0.065 g (81%); mp 85.9−88.8 °C. ^1H NMR ($CDCl_3$, 400 MHz): δ 7.54−7.52 (m, 2H), 7.42 (d, J = 8.3 Hz, 1H), 7.34−7.33 (m, 4H), 7.27 (t, J = 7.4 Hz, 1H), 7.20 (d, J = 7.7 Hz, 2H), 7.13 (t, J = 7.4 Hz, 1H), 7.08 (d, J = 7.7 Hz, 2H), 4.13 (s, 2H), 2.27 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.8, 136.4, 136.0, 135.9, 131.6, 129.2, 129.0, 128.5, 128.5, 128.0, 125.6, 124.6, 122.9, 122.2, 120.3, 111.3, 97.6, 79.3, 30.3, 21.0. MS (EI, 70 eV; m/z (relative intensity)): 323 [M + 1, (25)], 322 (100), 321 (38), 307 (46), 305 (23), 245 (40), 231 (19), 202 (23), 153 (15), 138 (17), 77 (12). HRMS: calcd for $C_{24}H_{18}O$ (M + H^+) 323.1430, found 323.1444.

*3-(3-Methylbenzyl)-2-(phenylethynyl)benzofuran (**2l**).* Obtained as a pallid yellow solid. Yield: 0.066 g (82%); mp 119.3−120.6 °C. ^1H NMR ($CDCl_3$, 400 MHz): δ 7.55−7.53 (m, 2H), 7.41 (d, J = 8.3 Hz, 1H), 7.35−7.31 (m, 4H), 7.26 (t, J = 8.3 Hz, 1H), 7.15−7.11 (m, 4H), 6.98 (d, J = 7.0 Hz, 1H) 4.13 (s, 2H), 2.27 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.8, 139.0, 138.1, 136.5, 131.6, 129.4, 129.0, 128.5, 128.5, 128.1, 127.2, 125.7, 125.7, 124.5, 123.0, 122.2, 120.3, 111.3, 97.7, 79.3, 30.6, 21.5. MS (EI, 70 eV; m/z (relative intensity)): 323 [M + 1, (29)], 322 (100), 321 (38), 307 (36), 305 (21), 245 (32), 231 (30), 202 (25), 153 (16), 138 (16). Anal. Calcd for $C_{24}H_{18}O$: C, 89.41; H, 5.63. Found: C, 89.55; H, 5.67.

*3-(4-Methoxybenzyl)-2-(phenylethynyl)benzofuran (**2m**).* Obtained as a pallid yellow solid. Yield: 0.076 g (90%); mp 51.3−52.5 °C. ^1H NMR ($CDCl_3$, 400 MHz): δ 7.55−7.53 (m, 2H), 7.42 (d, J = 8.2 Hz, 1H), 7.34−7.32 (m, 4H), 7.29 (d, J = 7.2 Hz, 1H), 7.24 (d, J = 8.7 Hz, 2H), 7.13 (t, J = 7.2 Hz, 1H), 6.80 (d, J = 8.7 Hz, 2H) 4.11 (s, 2H), 3.71 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 158.3, 154.8, 136.3, 131.6, 131.1, 129.6, 129.0, 128.5, 128.0, 125.7, 124.8, 122.9, 122.1, 120.3, 114.0, 111.3, 97.6, 79.3, 55.2, 29.8. MS (EI, 70 eV; m/z (relative intensity)): 339 [M + 1, (25)], 338 (100), 323 (23), 307 (21), 293 (10), 261 (18), 231 (9), 202 (11), 153 (10), 132 (10), 77 (9). Anal. Calcd for $C_{24}H_{18}O_2$: C, 85.18; H, 5.36. Found: C, 85.27; H, 5.43.

*3-(4-Chlorobenzyl)-2-(phenylethynyl)benzofuran (**2n**).* Obtained as a pallid yellow solid. Yield: 0.073 g (85%); mp 78.9−80.2 °C. ^1H NMR ($CDCl_3$, 400 MHz): δ 7.54−7.52 (m, 2H), 7.43 (d, J = 8.3 Hz, 1H), 7.36−7.35 (m, 3H), 7.32−7.28 (m, 2H), 7.24 (m, 4H), 7.16 (t, J = 7.4 Hz, 1H), 4.13 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.7, 137.5, 136.6, 132.3, 131.6, 129.9, 129.1, 128.7, 128.5, 127.7, 125.8, 123.6, 123.0, 121.9, 120.0, 111.3, 97.8, 78.9, 30.0. MS (EI, 70 eV; m/z (relative intensity)): 344 [M + 1, (35)], 343 (33), 342 (100), 341 (32), 307 (50), 305 (31), 231 (28), 202 (27), 153 (27), 138 (33), 125 (22). Anal. Calcd for $C_{23}H_{15}ClO$: C, 80.58; H, 4.41. Found: C, 80.66; H, 4.49.

*3-Pentyl-2-(phenylethynyl)benzofuran (**2o**).* Obtained as a pallid yellow oil. Yield: 0.035 g (49%). ^1H NMR ($CDCl_3$, 400 MHz): δ 7.57−7.52 (m, 3H), 7.42 (d, J = 8.2 Hz, 1H), 7.37−7.34 (m, 3H), 7.32 (t, J = 7.1 Hz, 1H), 7.25−7.21 (m, 1H), 2.83 (t, J = 7.4 Hz, 2H), 1.77 (qui, J = 7.3 Hz, 2H), 1.41−1.36 (m, 4H), 0.90 (t, J = 6.9 Hz, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.6, 135.8, 131.5, 128.8, 128.4, 128.4, 125.9, 125.4m 122.7, 122.3, 119.9, 111.2, 97.2, 79.4, 31.5, 28.8, 24.2, 22.4, 14.0. MS (EI, 70 eV; m/z (relative intensity)): 289 [M + 1, (12)], 288 (50), 232 (21), 231 (100), 207 (12), 202 (32), 129 (6). HRMS: calcd for $C_{21}H_{20}O$ (M + Na^+) 311.1406, found 311.1417.

*3-Benzyl-5-methyl-2-(phenylethynyl)benzofuran (**2p**).* Obtained as a pallid yellow solid. Yield: 0.060 g (75%); mp 165.1−167.0 °C. ^1H NMR ($CDCl_3$, 400 MHz): δ 7.55−7.52 (m, 2H), 7.36−7.32 (m, 5H), 7.27 (t, J = 7.7 Hz, 3H), 7.22−7.17 (m, 1H), 7.13−7.09 (m, 2H), 4.15 (s, 2H), 2.36 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 153.2, 139.2, 136.6, 132.4, 131.6, 128.9, 128.6, 128.5, 128.4, 128.0, 127.0, 126.4, 124.0, 122.2, 119.8, 110.8, 97.4, 79.4, 30.6, 21.3. MS (EI, 70 eV; m/z (relative intensity)): 323 [M + 1, (25)], 322 (100), 321 (46), 245 (55), 215 (18), 202 (23), 153 (23), 138 (15), 91 (17). HRMS: calcd for $C_{24}H_{18}O$ (M + Na^+) 345.1250, found 345.1268.

*3-Benzyl-2-((4-chlorophenyl)ethynyl)-5-methylbenzofuran (**2q**).* Obtained as a white solid. Yield: 0.065 g (73%); mp 139.8−142.9 °C. ^1H NMR ($CDCl_3$, 400 MHz): δ 7.45 (d, J = 8.6 Hz, 2H), 7.33−7.26 (m, 7H), 7.23−7.18 (m, 1H), 7.12 (dd, J = 10.5 Hz, J = 1.2 Hz, 2H), 4.14 (s, 2H), 2.36 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 153.3, 139.0, 136.3, 135.0, 132.7, 132.5, 128.8, 128.5, 127.9, 127.2, 126.4, 124.4, 120.6, 119.9, 110.8, 96.3, 80.3, 30.6, 21.3. MS (EI, 70 eV; m/z (relative intensity)): 358 [M + 1, (31)], 357 (36), 356 (100), 355 (40), 279 (23), 245 (42), 215 (25), 159 (34), 153 (24), 138 (33), 91 (49). Anal. Calcd for $C_{24}H_{17}ClO$: C, 80.78; H, 4.80. Found: C, 80.94; H, 4.88.

*3-Benzyl-5-methoxy-2-(phenylethynyl)benzofuran (**2r**).* Obtained as a pallid yellow solid. Yield: 0.064 g (76%); mp 97.4−99.3 °C. ^1H NMR ($CDCl_3$, 400 MHz): δ 7.56−7.53 (m, 2H), 7.36−7.26 (m, 8H), 7.20 (t, J = 7.1 Hz, 1H), 6.91 (dd, J = 8.9 Hz, J = 2.6 Hz, 1H), 6.73 (d, J = 2.4 Hz, 1H), 4.15 (s, 2H), 3.73 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.1, 149.8, 139.0, 137.2, 131.6, 128.9, 128.6, 128.5, 128.4, 126.4, 124.2, 122.2, 114.4, 111.7, 102.7, 97.5, 79.3, 55.8, 30.7. MS (EI, 70 eV; m/z (relative intensity)): 339 [M + 1, (26)], 338 (100), 337 (29), 261 (34), 189 (19), 176 (13), 150 (12), 132 (14), 91 (25). Anal. Calcd for $C_{24}H_{18}O_2$: C, 85.18; H, 5.36. Found: C, 85.52; H, 5.41.

*3-Benzyl-2-(phenylethynyl)furo[3,2-b]pyridine (**2s**).* Obtained as a pallid brown solid. Yield: 0.051 g (67%); mp 104.5−106.6 °C. ^1H NMR ($CDCl_3$, 400 MHz): δ 8.57 (dd, J = 4.7 Hz, J = 1.2 Hz, 1H), 7.64 (d, J = 8.3 Hz, 1H), 7.55−7.52 (m, 2H), 7.47 (d, J = 7.6 Hz, 2H), 7.37−7.35 (m, 3H), 7.26 (t, J = 7.3 Hz, 2H), 7.20−7.15 (m, 2H), 4.27 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 148.0, 146.9, 146.4, 140.0, 139.2, 131.7, 129.4, 128.9, 128.5, 128.5, 126.3, 125.1, 121.6, 119.9, 117.8, 99.3, 78.8, 29.2. MS (EI, 70 eV; m/z (relative intensity)): 310 [M + 1, (17)], 309 (84), 308 (100), 307 (19), 306 (13), 280 (17), 278 (19), 232 (11), 153 (35), 139 (15), 91 (11). Anal. Calcd for $C_{22}H_{15}NO$: C, 85.41; H, 4.89. Found: C, 85.59; H, 4.95.

*3-Benzyl-2-((4-chlorophenyl)ethynyl)furo[3,2-b]pyridine (**2t**).* Obtained as a pallid yellow solid. Yield: 0.052 g (61%); mp 131.0−132.7 °C. ^1H NMR ($CDCl_3$, 400 MHz): δ 8.57 (dd, J = 4.7 Hz, J = 1.1 Hz, 1H), 7.64 (dd, J = 8.3 Hz, J = 1.1 Hz, 1H), 7.45 (d, J = 8.5 Hz, 4H), 7.33 (d, J = 8.5 Hz, 2H), 7.28−7.16 (m, 4H), 4.26 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 148.1, 146.8, 146.5, 139.6, 139.0, 135.6, 132.8, 128.9, 128.8, 128.4, 126.4, 125.4, 120.1, 117.8, 98.0, 79.7, 29.2. MS (EI, 70 eV; m/z (relative intensity)): 345 [M + 1, (25)], 344 (50), 343 (96), 342 (100), 308 (23), 307 (33), 306 (24), 278 (28), 253 (23),

154 (72), 139 (35), 135 (23), 125 (23), 91 (36). HRMS: calcd for $C_{22}H_{14}ClNO$ (M + Na^+) 366.0656, found 366.0673.

*3-Benzyl-2-(naphthalen-2-ylethynyl)furo[3,2-b]pyridine (**2u**).* Obtained as a pallid yellow solid. Yield: 0.072 g (81%); mp 124.5−127.8 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.57 (dd, J = 4.7 Hz, J = 1.2 Hz, 1H), 8.05 (s, 1H), 7.82−7.80 (m, 3H), 7.65 (dd, J = 8.3 Hz, J = 1.3 Hz, 1H), 7.56 (dd, J = 8.5 Hz, J = 1.6 Hz, 1H), 7.51−7.49 (m, 4H), 7.28 (t, J = 7.3 Hz, 2H), 7.22−7.16 (m, 2H), 4.31 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 148.1, 146.9, 146.4, 140.1, 139.2, 133.3, 132.9, 132.1, 128.9, 128.5, 128.3, 128.0, 127.9, 127.8, 127.3, 126.9, 126.4, 125.1, 120.0, 118.8, 117.8, 99.8, 79.1, 29.3. MS (EI, 70 eV; m/z (relative intensity)): 360 [M + 1, (20)], 359 (95), 358 (100), 328 (20), 253 (27), 207 (20), 179 (70), 164 (31), 163 (26), 151 (20), 150 (21), 135 (22). 91 (23). HRMS: calcd for $C_{26}H_{17}NO$ (M + Na^+) 382.1202, found 382.1211.

*3-Benzyl-2-phenylbenzofuran (**2v**).* Obtained as a white solid. Yield: 0.041 g (58%); mp 77.8−79.3 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.75 (d, J = 8.1 Hz, 2H), 7.51 (d, J = 7.7 Hz, 1H), 7.40 (t, J = 7.2 Hz, 2H), 7.33 (d, J = 7.2 Hz, 2H), 7.27−7.24 (m, 5H), 7.21−7.17 (m, 1H), 7.14 (t, J = 7.4 Hz, 1H), 4.28 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.2, 152.2, 139.3, 131.0, 130.6, 128.7, 128.7, 128.4, 128.2, 127.0, 126.3, 124.5, 122.6, 120.0, 113.8, 111.1, 30.2. MS (EI, 70 eV; m/z (relative intensity)): 285 [M + 1, (21)], 284 (93), 283 (22), 207 (100), 178 (44), 176 (14), 91 (10), 77 (14). Anal. Calcd for $C_{21}H_{16}O$: C, 88.70; H, 5.67. Found: C, 88.93; H, 5.71.

General Procedure for the Synthesis of 12*H*-Benzoannulenes 3. To a solution of 2-alkynylphenyl propargyl ether **1** (0.25 mmol) in dry DMF (3 mL) was added *t*-BuOK (0.25 mmol). The resulting solution was stirred at 60 °C under an argon atmosphere until complete consumption of the starting material. The progress of the reaction was monitored by TLC. The mixture was cooled to room temperature, dissolved in ethyl acetate, washed with a saturated solution of NH_4Cl, dried with $MgSO_4$, and concentrated in vacuo. The residue was purified by column chromatography over silica gel to provide the 12*H*-benzoannulene **3**. Column chromatography was carried out using hexane as eluent except for **3d**,**e**,**l**, for which hexane/ethyl acetate (99/1) was used as eluent, and **3r**−**t**, for which hexane/ethyl acetate (97/3) was used as eluent.

*7-Phenyl-12H-benzo[4,5]cyclohepta[1,2-b]benzofuran (**3a**).* Obtained as a white solid. Yield: 0.067 g (87%); mp 124.3−126.6 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.63−7.61 (m, 1H), 7.47 (d, J = 7.2 Hz, 2H), 7.40−7.28 (m, 6H), 7.22−7.21 (m, 2H), 7.14 (s, 1H), 7.07 (s, 2H), 3.80 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.1, 150.8, 145.9, 143.8, 139.0, 137.4, 130.8, 129.4, 129.1, 128.5, 128.1, 127.8, 127.7, 125.5, 124.2, 122.6, 118.7, 118.0, 117.2, 111.3, 29.8. MS (EI, 70 eV; m/z (relative intensity)): 309 [M + 1, (23)], 308 (100), 307 (70), 293 (7), 276 (14), 231 (34), 202 (10), 153 (15), 138 (13), 125 (7). Anal. Calcd for $C_{23}H_{16}O$: C, 89.58; H, 5.23. Found: C, 89.70; H, 5.30.

*7-(p-Tolyl)-12H-benzo[4,5]cyclohepta[1,2-b]benzofuran (**3b**).* Obtained as a white solid. Yield: 0.049 g (61%); mp 148.7−150.2 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.64−7.62 (m, 1H), 7.41−7.36 (m, 3H), 7.32−7.27 (m, 2H), 7.23−7.18 (m, 4H), 7.14 (s, 1H), 7.11−7.05 (m, 2H), 3.80 (s, 2H), 2.38 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.2, 151.0, 145.9, 141.0, 139.1, 137.6, 137.6, 130.8, 129.4, 129.2, 129.0, 128.1, 127.9, 125.4, 124.1, 122.5, 118.7, 117.5, 117.1, 111.2, 29.8, 21.1. MS (EI, 70 eV; m/z (relative intensity)): 323 [M + 1, (30)], 322 (100), 321 (66), 307 (25), 276 (11), 231 (29), 207 (14), 153 (27), 138 (16). HRMS: calcd for $C_{24}H_{18}O$ (M + Na^+) 345.1250, found 345.1262.

*7-(m-Tolyl)-12H-benzo[4,5]cyclohepta[1,2-b]benzofuran (**3c**).* Obtained as a pallid yellow solid. Yield: 0.065 g (81%); mp 112.8−115.4 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.63−7.61 (m, 1H), 7.40−7.38 (m, 1H), 7.30−7.19 (m, 7H), 7.14 (S, 2H), 7.10−7.04 (m, 2H), 3.80 (s, 2H), 2.36 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.2, 150.9, 146.1, 143.8, 139.0, 138.1, 137.6, 130.9, 129.8, 129.4, 128.5, 128.4, 128.1, 127.9, 126.3, 125.5, 124.2, 122.6, 118.7, 117.9, 117.2, 111.3, 29.8, 21.5. MS (EI, 70 eV; m/z (relative intensity)): 323 [M + 1, (27)], 322 (100), 307 (20), 305 (20), 276 (10), 231 (27), 202 (8), 153 (22), 138 (13). HRMS: calcd for $C_{24}H_{18}O$ (M + Na^+) 345.1250, found 345.1260.

*7-(4-Methoxyphenyl)-12H-benzo[4,5]cyclohepta[1,2-b]benzofuran (**3d**).* Obtained as a white solid. Yield: 0.061 g (72%); mp 170.5−171.9 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.65−7.63 (m, 1H), 7.40 (d, J = 8.7 Hz, 3H), 7.32−7.30 (m, 2H), 7.26−7.22 (m, 2H), 7.13−7.07 (m, 3H), 6.94 (d, J = 8.7 Hz, 2H), 3.84 (s, 3H), 3.80 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 159.4, 156.0, 151.0, 145.5, 139.1, 137.6, 136.3, 133.2, 130.8, 130.2, 129.4, 128.1, 125.4, 124.1, 122.5, 118.6, 117.0, 114.2, 113.9, 111.2, 55.3, 29.8. MS (EI, 70 eV; m/z (relative intensity)): 339 [M + 1, (27)], 338 (100), 337 (33), 307 (12), 293 (33), 231 (26), 152 (17), 131 (16). HRMS: calcd for $C_{24}H_{18}O_2$ (M + H^+) 339.1380, found 339.1391.

*7-(3-Methoxyphenyl)-12H-benzo[4,5]cyclohepta[1,2-b]benzofuran (**3e**).* Obtained as a yellow solid. Yield: 0.077 g (91%); mp 125.6−128.9 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.64−7.62 (m, 1H), 7.41−7.39 (m, 1H), 7.31−7.27 (m, 3H), 7.24−7.21 (m, 2H), 7.16 (s, 1H), 7.12−7.03 (m, 4H), 6.88 (dd, J = 8.1 Hz, J = 2.2 Hz, 1H), 3.81 (s, 2H), 3.79 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 159.8, 156.1, 150.8, 145.8, 145.2, 139.0, 137.4, 130.8, 129.5, 128.1, 127.8, 125.6, 124.3, 122.6, 121.7, 118.8, 118.1, 117.3, 114.7, 113.4, 111.3, 55.3, 29.8. MS (EI, 70 eV; m/z (relative intensity)): 339 [M + 1, (25)], 338 (100), 337 (52), 321 (17), 293 (17), 231 (29), 153 (11), 138 (11). HRMS: calcd for $C_{24}H_{18}O_2$ (M + Na^+) 361.1199, found 361.1209.

*7-(4-Fluorophenyl)-12H-benzo[4,5]cyclohepta[1,2-b]benzofuran (**3f**).* Obtained as a pallid yellow solid. Yield: 0.059 g (72%); mp 141.5−142.8 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.65−7.62 (m, 1H), 7.44−7.39 (m, 3H), 7.33−7.29 (m, 2H), 7.24−7.22 (m, 2H), 7.09−7.03 (m, 5H), 3.80 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.5 (d, ^1J = 247.0 Hz), 156.2, 150.7, 144.7, 139.8 (d, ^4J = 3.7 Hz), 139.0, 137.3, 130.8 (d, ^3J = 8.0 Hz), 130.6, 129.6, 128.3, 127.8, 125.6, 124.4, 122.7, 118.8, 118.1, 117.5, 115.4 (d, ^2J = 21.2 Hz), 111.3, 29.8. MS (EI, 70 eV; m/z (relative intensity)): 339 [M + 1, (27)], 338 (100), 337 (33), 307 (12), 293 (33), 231 (26), 152 (17), 131 (16). Anal. Calcd for $C_{23}H_{15}FO$: C, 84.64; H, 4.63. Found: C, 84.79; H, 4.70.

*7-(4-Chlorophenyl)-12H-benzo[4,5]cyclohepta[1,2-b]benzofuran (**3g**).* Obtained as a pallid yellow solid. Yield: 0.065 g (76%); mp 177.1−179.6 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.65−7.62 (m, 1H), 7.41−7.28 (m, 7H), 7.25−7.22 (m, 2H), 7.11−7.06 (m, 2H), 7.04 (d, J = 7.5 Hz, 1H), 3.80 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.2, 150.6, 144.5, 142.2, 139.1, 137.1, 133.7, 130.6, 130.3, 129.6, 128.7, 128.3, 127.7, 125.6, 124.4, 122.6, 118.8, 118.3, 117.6, 111.3, 29.7. MS (EI, 70 eV; m/z (relative intensity)): 344 [M + 1, (36)], 343 (44), 342 (100), 341 (64), 307 (24), 305 (34), 276 (25), 231 (46), 202 (14), 153 (48), 138 (42), 127 (19), 125 (21). HRMS: calcd for $C_{23}H_{15}ClO$ (M + Na^+) 365.0704, found 365.0721.

*7-(Thiophen-3-yl)-12H-benzo[4,5]cyclohepta[1,2-b]benzofuran (**3h**).* Obtained as a pallid brown solid. Yield: 0.061 g (78%); mp 149.9−152.0 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.64−7.62 (m, 1H), 7.41−7.39 (m, 1H), 7.33−7.29 (m, 5H), 7.25−7.21 (m, 4H), 7.14−7.10 (m, 1H), 3.79 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.1, 150.8, 144.4, 140.0, 139.1, 136.9, 130.5, 129.5, 128.1, 128.1, 127.8, 125.7, 125.5, 124.2, 123.7, 122.6, 118.7, 117.5, 117.0, 111.3, 29.8. MS (EI, 70 eV; m/z (relative intensity)): 314 (100), 281 (26), 268 (13), 255 (13), 239 (12), 231 (14), 134 (12). HRMS: calcd for $C_{21}H_{14}OS$ (M + H^+) 315.0838, found 315.0853.

*12H-Benzo[4,5]cyclohepta[1,2-b]benzofuran (**3i**).* Obtained as a white solid. Yield: 0.017 g (29%); mp 100.1−102.8 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.65−7.63 (m, 1H), 7.42−7.39 (m, 1H), 7.35−7.21 (m, 6H), 7.03 (d, J = 11.9 Hz, 1H), 6.89 (d, J = 11.9 Hz, 1H), 3.85 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 155.9, 150.9, 135.9, 135.8, 133.1, 129.9, 129.5, 129.0, 128.2, 126.2, 124.3, 122.5, 119.2, 118.8, 115.3, 111.2, 29.5. MS (EI, 70 eV; m/z (relative intensity)): 233 [M + 1, (13)], 232 (75), 231 (100), 202 (30), 176 (7), 116 (12), 101 (14), 88 (9). Anal. Calcd for $C_{17}H_{12}O$: C, 87.90; H, 5.21. Found: C, 88.18; H, 5.28.

*9-Methyl-7-phenyl-12H-benzo[4,5]cyclohepta[1,2-b]benzofuran (**3j**).* Obtained as a white solid. Yield: 0.056 g (70%); mp 194.0−196.8 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.65−7.63 (m, 1H), 7.48 (d, J = 7.0 Hz, 2H), 7.42−7.33 (m, 4H), 7.24−7.21 (m, 3H), 7.14−7.12 (m, 2H), 6.88 (s, 1H), 3.79 (s, 2H), 2.16 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.0, 150.8, 145.9, 143.9, 137.3, 136.4, 135.0, 131.2, 130.3,

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129.1, 128.5, 128.0, 127.8, 127.7, 124.2, 122.5, 118.7, 118.1, 117.5, 111.2, 29.3, 20.9. MS (EI, 70 eV; *m*/*z* (relative intensity)): 323 [M + 1, (24)], 322 (100), 321 (58), 307 (24), 305 (19), 276 (10), 245 (29), 153 (24), 138 (17). HRMS: calcd for $C_{24}H_{18}O$ (M + H^+) 323.1430, found 323.1441.

*8-Methyl-7-phenyl-12H-benzo[4,5]cyclohepta[1,2-b]benzofuran (**3k**).* Obtained as a pallid yellow solid. Yield: 0.050 g (62%); mp 212.1−213.2 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.63−7.61 (m, 1H), 7.39 (d, *J* = 6.9 Hz, 3H), 7.35 (t, *J* = 7.2 Hz, 3H), 7.29 (d, *J* = 7.0 Hz, 1H), 7.24−7.20 (m, 4H), 6.96 (t, *J* = 4.0 Hz, 1H), 3.95 (d, *J* = 13.6 Hz, 1H), 3.50 (d, *J* = 13.6 Hz, 1H), 1.78 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 155.9, 150.8, 146.2, 143.8, 143.7, 137.8, 156.6, 129.3, 128.7, 128.5, 127.5, 127.3, 126.9, 125.0, 124.2, 122.5, 120.0, 119.5, 118.7, 111.3, 30.0, 23.0. MS (EI, 70 eV; *m*/*z* (relative intensity)): 323 [M + 1, (30)], 322 (100), 321 (31), 307 (30), 305 (20), 245 (58), 231 (13), 153 (28), 138 (18). Anal. Calcd for $C_{24}H_{18}O$: C, 89.41; H, 5.63. Found: C, 89.59; H, 5.69.

*9-Methoxy-7-phenyl-12H-benzo[4,5]cyclohepta[1,2-b]-benzofuran (**3l**).* Obtained as a pallid yellow solid. Yield: 0.071 g (84%); mp 151.9−153.9 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.63−7.61 (m, 1H), 7.49 (d, *J* = 6.9 Hz, 2H), 7.41−7.31 (m, 4H), 7.24−7.21 (m, 3H), 7.13 (s, 1H), 6.87 (dd, *J* = 8.4 Hz, *J* = 2.7 Hz, 1H), 6.61 (d, *J* = 2.7 Hz, 1H), 3.78 (s, 2H), 3.58 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 157.3, 156.1, 150.8, 145.6, 143.6, 138.5, 132.1, 129.1, 129.0, 128.5, 127.8, 124.3, 122.6, 118.8, 118.4, 117.8, 116.3, 115.0, 111.3, 55.3, 28.8. MS (EI, 70 eV; *m*/*z* (relative intensity)): 339 [M + 1, (22)], 338 (100), 321 (15), 305 (17), 292 (13), 261 (18), 161 (10), 153 (16), 138 (15). Anal. Calcd for $C_{24}H_{18}O_2$: C, 85.18; H, 5.36. Found: C, 85.24; H, 5.40.

*9-Chloro-7-phenyl-12H-benzo[4,5]cyclohepta[1,2-b]benzofuran (**3m**).* Obtained as a pallid yellow solid. Yield: 0.068 g (79%); mp 168.7−169.8 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.63−7.61 (m, 1H), 7.46−7.33 (m, 6H), 7.28−7.22 (m, 4H), 7.17 (s, 1H), 7.06 (s, 1H), 3.76 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.2, 150.6, 144.5, 143.0, 139.0, 137.3, 131.4, 130.3, 129.3, 129.3, 129.0, 128.7, 128.0, 127.5, 124.5, 122.7, 119.1, 118.8, 117.4, 111.4, 29.1. MS (EI, 70 eV; *m*/*z* (relative intensity)): 344 [M + 1, (34)], 343 (41), 342 (100), 341 (58), 307 (33), 305 (33), 276 (26), 265 (31), 153 (47), 138 (37), 125 (18). HRMS: calcd for $C_{23}H_{15}ClO$ (M + Na^+) 365.0704, found 365.0719.

*7-Phenyl-14H-naphtho[1′,2′:4,5]cyclohepta[1,2-b]benzofuran (**3n**).* Obtained as a pallid yellow solid. Yield: 0.073 g (82%); mp 183.9−185.1 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.55 (d, *J* = 8.6 Hz, 1H), 7.78−7.72 (m, 2H), 7.59 (t, *J* = 7.2 Hz, 1H), 7.49 (d, *J* = 7.6 Hz, 2H), 7.45 (t, *J* = 6.9 Hz, 2H), 7.41−7.31 (m, 5H), 7.25−7.15 (m, 3H), 4.09 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.6, 151.6, 146.6, 143.6, 134.3, 133.5, 130.4, 129.1, 128.7, 128.5, 128.0, 127.9, 127.5, 126.6, 126.0, 125.1, 124.5, 124.0, 122.8, 118.7, 118.1, 111.4, 22.9. MS (EI, 70 eV; *m*/*z* (relative intensity)): 359 [M + 1, (26)], 358 (100), 357 (64), 355 (13), 281 (29), 178 (15), 171 (15), 163 (15), 162 (11), 157 (15), 150 (11). Anal. Calcd for $C_{27}H_{18}O$: C, 90.47; H, 5.06. Found: C, 90.53; H, 5.10.

*2-Methyl-7-phenyl-12H-benzo[4,5]cyclohepta[1,2-b]benzofuran (**3o**).* Obtained as a pallid yellow solid. Yield: 0.056 g (70%); mp 152.8−154.0 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.55 (d, *J* = 6.8 Hz, 2H), 7.50 (s, 1H), 7.46 (t, *J* = 7.0 Hz, 2H), 7.42−7.35 (m, 4H), 7.21 (s, 1H), 7.16−7.14 (m, 2H), 7.11 (dd, *J* = 8.3 Hz, *J* = 1.2 Hz, 1H), 3.87 (s, 2H), 2.53 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.6, 151.0, 145.6, 143.9, 139.1, 137.5, 132.0, 130.7, 129.4, 129.1, 128.5, 128.1, 127.9, 127.7, 125.5, 125.5, 118.6, 118.2, 117.1, 110.8, 29.8, 21.4. MS (EI, 70 eV; *m*/*z* (relative intensity)): 323 [M + 1, (25)], 322 (100), 321 (62), 307 (9), 276 (9), 245 (34), 160 (10), 159 (13), 153 (21), 145 (11), 138 (13). Anal. Calcd for $C_{24}H_{18}O$: C, 89.41; H, 5.63. Found: C, 89.59; H, 5.69.

*7-(4-Chlorophenyl)-2-methyl-12H-benzo[4,5]cyclohepta[1,2-b]-benzofuran (**3p**).* Obtained as a pallid yellow solid. Yield: 0.045 g (50%); mp 190.2−192.9 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.43 (s, 1H), 7.40 (d, *J* = 8.7 Hz, 2H), 7.36 (d, *J* = 8.7 Hz, 2H), 7.33−7.31 (m, 2H), 7.29 (d, *J* = 8.3 Hz, 1H), 7.10−7.07 (m, 2H), 7.05 (t, *J* = 7.5 Hz, 2H), 3.79 (s, 2H), 2.46 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.7, 150.7, 144.2, 142.2, 139.1, 137.1, 133.6, 132.1, 130.5, 130.3, 129.6, 128.7, 128.2, 127.7, 125.7, 125.6, 118.6, 118.4, 117.4, 110.8, 29.7, 21.4. MS (EI, 70 eV; *m*/*z* (relative intensity)): 358 [M + 1, (34)], 357 (42), 356 (100), 355 (57), 321 (17), 319 (21), 245 (44), 207 (12), 159 (40), 153 (40), 138 (22). Anal. Calcd for $C_{24}H_{17}ClO$: C, 80.78; H, 4.80. Found: C, 80.94; H, 4.88.

*2-Methoxy-7-phenyl-12H-benzo[4,5]cyclohepta[1,2-b]-benzofuran (**3q**).* Obtained as a white solid. Yield: 0.063 g (74%); mp 54.9−57.8 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.52 (d, *J* = 7.2 Hz, 2H), 7.47−7.34 (m, 6H), 7.18 (s, 1H), 7.15−7.13 (m, 3H), 6.89 (dd, *J* = 8.9 Hz, *J* = 2.3 Hz, 1H), 3.94 (s, 3H), 3.86 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.1, 151.7, 151.2, 145.7, 143.8, 139.0, 137.5, 130.7, 129.3, 129.0, 128.4, 128.3, 128.1, 127.6, 125.5, 118.1, 117.3, 112.9, 111.6, 101.5, 56.0, 29.8. MS (EI, 70 eV; *m*/*z* (relative intensity)): 339 [M + 1, (24)], 338 (100), 337 (43), 294 (16), 265 (18), 261 (25), 239 (14), 189 (12), 132 (21), 119 (14). HRMS: calcd for $C_{24}H_{18}O_2$ (M + Na^+) 361.1199, found 361.1214.

*7-Phenyl-12H-benzo[5′,6′]cyclohepta[1′,2′:4,5]furo[3,2-b]-pyridine (**3r**).* Obtained as a pallid yellow solid. Yield: 0.045 g (58%); mp 158.8−161.0 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.55 (d, *J* = 4.7 Hz, 1H), 7.67 (d, *J* = 8.2 Hz, 1H), 7.51−7.33 (m, 7H), 7.17−7.06 (m, 4H), 4.03 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.6, 149.4, 148.4, 146.5, 145.5, 143.5, 139.3, 137.2, 130.9, 129.9, 129.0, 128.6, 128.5, 128.1, 125.7, 118.6, 117.8, 117.4, 117.4, 28.1. MS (EI, 70 eV; *m*/*z* (relative intensity)): 310 [M + 1, (22)], 309 (100), 308 (82), 306 (14), 278 (13), 232 (22), 207 (18), 154 (23), 147 (21), 139 (14). Anal. Calcd for $C_{22}H_{15}NO$: C, 85.41; H, 4.89. Found: C, 85.52; H, 4.93.

*7-(4-Chlorophenyl)-12H-benzo[5′,6′]cyclohepta[1′,2′:4,5]furo-[3,2-b]pyridine (**3s**).* Obtained as a pallid yellow solid. Yield: 0.048 g (56%); mp 219.3−221.7 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.54 (d, *J* = 4.7 Hz, 1H), 7.67 (d, *J* = 8.2 Hz, 1H), 7.47−7.34 (m, 6H), 7.18−7.11 (m, 3H), 7.05 (d, *J* = 7.8 Hz, 1H), 4.02 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.3, 149.9, 146.9, 146.4, 145.6, 141.9, 139.3, 136.8, 134.0, 130.7, 130.3, 130.1, 128.9, 128.7, 125.7, 125.3, 118.6, 117.8, 117.7, 28.1. MS (EI, 70 eV; *m*/*z* (relative intensity)): 345 [M + 1, (32)], 344 (45), 343 (100), 342 (67), 308 (18), 307 (18), 306 (25), 278 (16), 232 (24), 207 (17), 154 (81), 139 (28), 125 (25). Anal. Calcd for $C_{22}H_{14}ClNO$: C, 76.86; H, 4.10. Found: C, 76.98; H, 4.18.

*7-(Naphthalen-2-yl)-12H-benzo[5′,6′]cyclohepta[1′,2′:4,5]furo-[3,2-b]pyridine (**3t**).* Obtained as a pallid yellow solid. Yield: 0.052 g (58%); mp 243.8−246.0 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.57 (d, *J* = 4.7 Hz, 1H), 7.80 (s, 1H), 7.87 (d, *J* = 8.0 Hz, 3H), 7.68 (d, *J* = 8.2 Hz, 1H), 7.58 (d, *J* = 8.5 Hz, 1H), 7.53−7.49 (m, 3H), 7.37 (t, *J* = 7.4 Hz, 1H), 7.26 (d, *J* = 11.3 Hz, 1H), 7.18−7.15 (m, 1H), 7.11−7.10 (m, 2H), 4.08 (s, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 154.6, 149.5, 148.3, 146.6, 145.6, 140.9, 139.4, 137.3, 133.4, 133.0, 131.0, 129.9, 128.7, 128.2, 128.1, 127.9, 127.6, 127.1, 126.4, 126.4, 125.7, 118.5, 117.9, 117.7, 117.6, 28.2. MS (EI, 70 eV; *m*/*z* (relative intensity)): 360 [M + 1, (27)], 359 (100), 358 (70), 357 (12), 356 (18), 328 (11), 232 (16), 179 (42), 178 (10), 164 (16), 150 (10). HRMS: calcd for $C_{26}H_{17}NO$ (M + Na^+) 382.1202, found 382.1216.

*2,2-Dimethyl-4-phenyl-1,2-dihydrooxepino[4,5-b]benzofuran (**3u**).* Obtained as a pallid yellow oil. Yield: 0.033 g (46%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.56−7.53 (m, 2H), 7.46 (t, *J* = 7.1 Hz, 1H), 7.33−7.21 (m, 6H), 6.40 (s, 1H), 4.28 (s, 2H), 1.99 (s, 3H), 1.66 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 189.5, 154.3, 147.2, 141.2, 134.1, 129.7, 128.5, 128.1, 128.1, 126.8, 125.9, 123.3, 114.3, 112.2, 46.4, 26.0, 20.8. MS (EI, 70 eV; *m*/*z* (relative intensity)): 291 [M + 1, (2)], 290 (10), 276 (16), 275 (81), 199 (17), 171 (100), 142 (27), 141 (25), 128 (98), 127 (25), 115 (34), 91 (34), 65 (14). Anal. Calcd for $C_{20}H_{18}O_2$: C, 82.73; H, 6.25. Found: C, 82.94; H, 6.30.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

Text, figures, and CIF files giving spectroscopic data for all new compounds, X-ray results, and detailed experimental procedures. This material is available free of charge via the Internet at http://pubs.acs.org.

AUTHOR INFORMATION

Corresponding Author

*gzeni@ufsm.br

Notes

The authors declare no competing financial interest.

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