有机化学 DOI: 10.6023/cjoc202304003 研究论文
Chinese Journal of Organic Chemistry ARTICLE

锡粉促进下 1,3-二取代-1,3-二氢异苯并呋喃化合物的合成

唐朵朵 黄丹凤* 王克虎 马 虎 冯 杨
任园园 王君姣 胡雨来
(西北师范大学化学化工学院 兰州 730070)

摘要 探究了锡粉促进下邻甲酰基查尔酮与烯丙基溴的串联烯丙基化/oxa-Michael 加成反应, 为合成具有潜在生物活性的 1,3-二取代-1,3-二氢异苯并呋喃提供了简便的方法. 该方法具有反应时间短, 操作简单, 产率优良等优点, 并进一步拓宽了锡粉促进下的反应类型.

关键词 锡粉; 烯丙基溴; 邻甲酰基查尔酮; 1,3-二氢异苯并呋喃

Tin Powder-Promoted Synthesis of 1,3-Disubstituted 1,3-Dihydroisobenzofuran Compounds

Tang, Duoduo Huang, Danfeng* Wang, Kehu Ma, Hu Feng, Yang
Ren, Yuanyuan Wang, Junjiao Hu, Yulai
(*College of Chemistry and Chemical Engineering*, *Northwest Normal University*, *Lanzhou 730070*)

Abstract An efficient approach for the construction of 1,3-disubstituted-1,3-dihydroisobenzofuran compounds was developed through tin powder mediated tandem allylation/oxa-Michael addition reaction of *o*-formyl chalcones with various allyl bromides under mild reaction conditions. This method is easy to operate and can tolerate various functional groups to give the corresponding 1,3-disubstituted-1,3-dihydroisobenzofuran compounds in good to excellent yields.

Keywords tin powder; allyl bromide; *o*-formyl chalcone; 1,3-dihydroisobenzofuran

1 Introduction

As an important oxygen-containing heterocycle, 1,3-dihydroisobenzofuran derivatives are widely found in natural products and drug molecules,[1] which exhibit impressive bioactivities such as antibacterial,[2] antidepressive,[1] anti-human immunodeficiency virus[3] and antihistamine activities.[4] They are also important building blocks in organic synthesis.[1] Besides, 1,3-disubstituted 1,3-dihydroisobenzofuran skeletons are frequently found in biologically and pharmaceutically active compounds, and some typical bioactive 1,3-disubstituted-1,3-dihydroisobenzofuran compounds are shown in Figure 1. Thus, the concise and efficient methods for the synthesis of 1,3-disubstituted-1,3-dihydroisobenzofuran derivatives are of significant importance. Traditionally, the tandem nucleophilic addition/oxa-Michael addition reaction of *o*-formyl chalcones with various nucleophiles is a major, direct and practical synthetic method with the advantages of mild conditions, simple operation and high product yields. For example, *o*-formyl chalcones can react with nitroalkanes,[5] $TMSCF_3$,[6] dimethyl diazomethylphosphates,[7] malononitriles,[8] benzyl mercaptans[9] and allyl borate pinacol esters[10] to produce 1,3-disubstituted-1,3-dihydroisobenzofurans (Scheme 1a). Other methods include nucleophilic allylation-heterocyclization,[11] addition/cyclization of *ortho*-lithiated aryloxiranes with carbonyl compounds,[12] hydrogenation of 1-cyano-3-phenylisobenzofurans,[4] tellurium-triggered domino reaction,[13] and photoredoxmediated tandem three-component process.[14]

On the other hand, since Mukaiyama[15] successfully reported the allylation reaction with the participation of tin powder in 1981, the allylation reaction promoted by tin powder has been extensively investigated. In our previous works, we explored not only the allylation reaction and allylation/cyclization reactions promoted by tin powder,[16] but also the C—C coupling reaction of benzyl carbocation promoted by tin powder,[17] and a series of homoallylic

* Corresponding author. E-mail: huangdf@nwnu.edu.cn
Received April 4, 2023; revised June 5, 2023; published online August 16, 2023.
Project supported by the National Natural Science Foundation of China (Nos. 21861033, 22061037).
国家自然科学基金(Nos. 21861033, 22061037)资助项目.

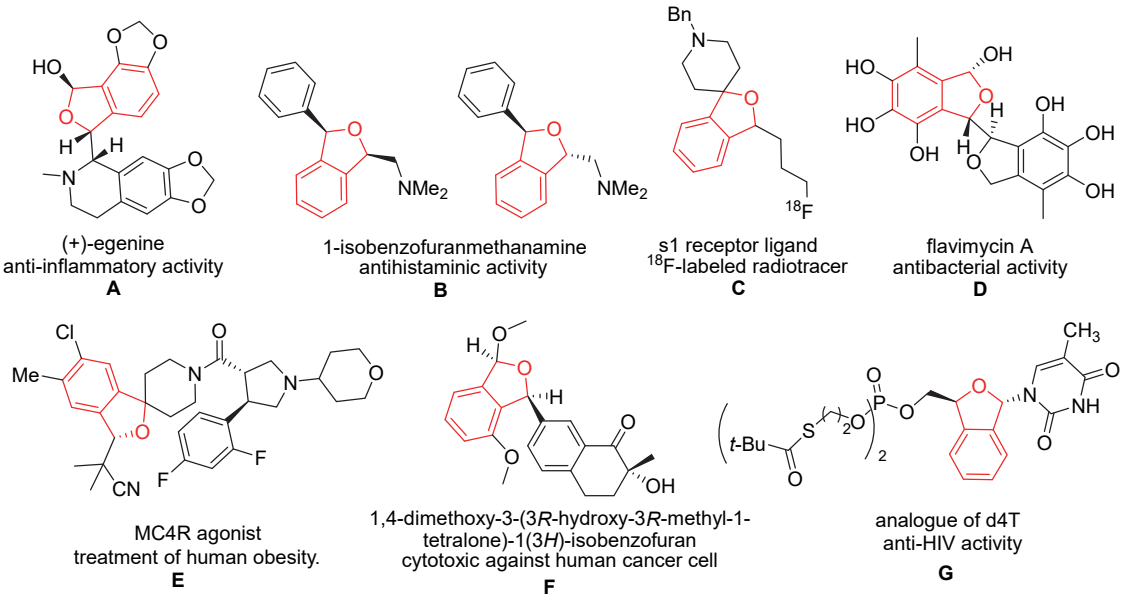
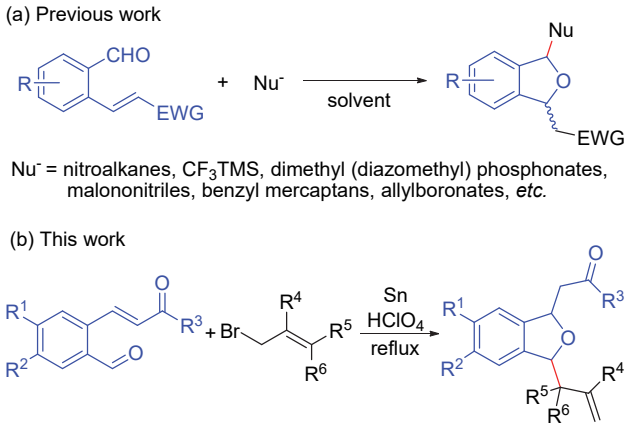


Figure 1 Selected bioactive molecules containing a 1,3-disubstituted 1,3-dihydroisobenzofuran scaffold

oxygen- or nitrogen-containing heterocyclic compounds have been synthesized. In order to further expand the tin powder-promoted reaction in the synthesis of oxygen-containing heterocyclic compounds, inspired by the work from the Huang group,[10] we herein report a "one-pot" tandem nucleophilic addition/oxa-Michael addition reaction of *o*-formyl chalcones with allyl bromides in the presence of tin powder, which provides a new method for the synthesis of 1,3-disubstituted-1,3-dihydroisobenzofurans (Scheme 1b).



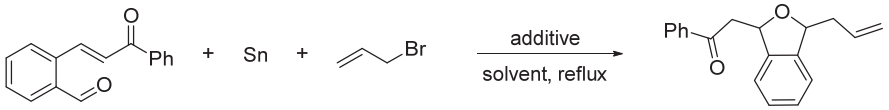
Scheme 1 Methods for synthesizing derivatives of phthalans by tandem nucleophilic addition/oxa-Michael addition reaction of *o*-formyl chalcones and nucleophiles

2 Results and discussion

In our initial investigations, *o*-formyl chalcone **1a** (0.2 mmol, 1.0 equiv.), allyl bromide **2a** (0.4 mmol, 2.0 equiv.) and tin powder (0.5 mmol, 2.5 equiv.) were refluxed in tetrahydrofuran (THF) at 70 ℃ for 12 h, and the tandem nucleophilic addition/oxa-Michael addition reaction occurred to give the desired product **3a** in 66% yield (Table 1, Entry 1). In our previous works, the addition of some Lewis acids or Brønsted acids into the tin powder promoted reactions would be beneficial to the reaction yields.[16] Thus, different acids were screened, and the results indicated that the addition of 0.2 equiv. of $Fe(OTf)_3$ or $HClO_4$ improved the product yield to 69% or 70% yield, respectively (Table 1, Entries 4～12). Due to the lower cost, $HClO_4$ was used as additive to check the other reaction parameters. The examination of the amount of $HClO_4$ showed that use of 0.5 equiv. of $HClO_4$ increased the product yield to 78% (Table 1, Entries 12～14). Finally, screening of different solvents indicated that ethanol was the most suitable solvent, which made the product yield increase to 83% (Table 1, Entry 19). Thus, the suitable reaction condition was determined that the reaction was conducted in ethanol with the substrate molar ratio of **1a**/**2a**/Sn to be 1∶2∶2.5 in the presence of 0.5 equiv. of $HClO_4$ (Table 1, Entry 19).

With the optimal reaction condition in hand, the different substituted *o*-formyl chalcones **1** were applied in the reaction to investigate the generality of the substrates (Table 2). When R^1 was a hydrogen atom and R^2 were aromatic groups, the results indicated that most of *o*-formyl chalcones with both electron-rich and electron-poor aromatic groups gave the corresponding products in good yields with almost equal equivalent of *trans*- and *cis*-isomers (Table 2, **3a**～**3g**). When R^2 were 2-naphthyl, 2-furanyl and 2-thienyl groups, the products **3h**～**3j** could also be obtained in good yields (Table 2, **3h**～**3j**). However, when *o*-formyl chalcone was (*E*)-2-((2-oxocyclohexylidene)methyl)benzaldehyde or (*E*)-2-(3-oxobut-1-en-1-yl)benzaldehyde, no desired product was generated (Table 2, **3k** and **3l**). This may be due to the weak electrophilicity of substrate **1k** or **1l**. Finally, the electronic effect of R^1 groups on *o*-formyl chalcones **1** on the reaction was examined. As indicated in Table 2, both electron-donating and

Table 1 Optimization of the reaction conditions[a]



1a **2a** **3a**

Entry	Molar ratio of **1a**∶**2a**∶Sn	Additive (equiv.)	Solvent	Time[b]/h	Yield[c]/%	*cis*∶*trans*[d][5]
1	1.0∶2.0∶2.5	None	THF	12	66	1.0∶2.4
2	1.0∶3.0∶3.5	None	THF	12	56	1.0∶1.0
3	1.0∶1.0∶1.5	None	THF	9	54	1.0∶1.2
4	1.0∶2.0∶2.5	$In(OTf)_3$ (0.2)	THF	6	50	2.2∶1.0
5	1.0∶2.0∶2.5	AgOTf (0.2)	THF	12	67	1.0∶2.0
6	1.0∶2.0∶2.5	$Fe(OTf)_3$ (0.2)	THF	7	69	1.0∶1.5
7	1.0∶2.0∶2.5	BF_3•Et_2O (0.2)	THF	8	58	1.6∶1.0
8	1.0∶2.0∶2.5	TsOH (0.2)	THF	8	63	1.1∶1.0
9	1.0∶2.0∶2.5	TfOH (0.2)	THF	8	54	1.0∶1.0
10	1.0∶2.0∶2.5	H_3PO_4 (0.2)	THF	9	36	1.3∶1.0
11	1.0∶2.0∶2.5	HCl (0.2)	THF	9	67	1.0∶1.0
12	1.0∶2.0∶2.5	$HClO_4$ (0.2)	THF	5	70	1.0∶1.2
13	1.0∶2.0∶2.5	$HClO_4$ (0.5)	THF	4	78	1.4∶1.0
14	1.0∶2.0∶2.5	$HClO_4$ (1)	THF	3	53	1.8∶1.0
15	1.0∶2.0∶2.5	$HClO_4$ (0.5)	Dioxane	1	58	1.2∶1.0
16	1.0∶2.0∶2.5	$HClO_4$ (0.5)	DCM	14	30	1.0∶1.8
17	1.0∶2.0∶2.5	$HClO_4$ (0.5)	Toluene	1	—	—
18	1.0∶2.0∶2.5	$HClO_4$ (0.5)	CH_3CN	1	53	1.0∶1.0
19	1.0∶2.0∶2.5	$HClO_4$ (0.5)	EtOH	1	83	1.0∶1.1

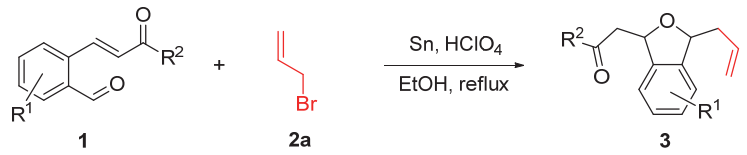
[a] All reactions were carried out by using 0.2 mmol of **1a**, 0.3～0.7 mmol of tin powder, 0.2～0.6 mmol of **2a**, solvent (2 mL), reflux. [b] **1a** was completely consumed. [c] Combined isolated yield of *cis*- and *trans*-isomers. [d] Molar ratio of *cis*- and *trans*-isomers was determined by ^1H NMR analysis.[10]

electron-withdrawing groups R^1 could exist on the phenyl rings of *o*-formyl chalcones **1**, and the corresponding products could be obtained in good yields (Table 2, **3m**～**3r**).

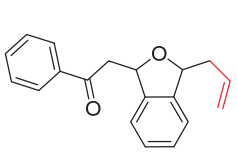
Next, various substituted allyl bromides were applied in the reaction. As indicated in Table 3, all of *β*- and *γ*-substituted allyl bromides could be used in the reactions to produce the corresponding products in moderate to excellent yields (Table 3). For instance, when 2-methyl allyl bromide was used in the reaction, the product **4a** was obtained in 51% yield. When the allyl bromides with substituents at 2-position were aromatic groups, such as phenyl, *p*-methyl-phenyl, *p*-chloro-phenyl, *p*-bromo-phenyl and 1-naphthyl groups, the corresponding products were also obtained in reasonable to good yields (Table 3, **4b**～**4h**). Afterwards, ethyl 2-(bromomethyl)acrylate and 2,3-dibromopropene were applied in the reaction, and the reactions occurred smoothly to produce the products **4i**～**4n** in good yields (Table 3, **4i**～**4n**). Finally, *γ*-substituted allyl bromides, such as cinnamyl bromide, 3,3-dimethyl-allyl bromide and 3-bromo-1-cyclohexene, were examined in the reaction. Unfortunately, only trace amounts of the target compounds were obtained under standard reaction conditions. A brief examination of the reaction conditions found that the target compounds could be obtained when tetrahydrofuran was used as solvent without the addition of $HClO_4$. As indicated in Table 3, the corresponding products **4o**～**4q** could be obtained in moderate yields.

On the basis of the literatures[18-25] and our experimental results, the reaction mechanism was tentatively proposed. As showed in Scheme 2, the carbonyl group of aldehyde group in *o*-formyl chalcones **1** is protonated by $HClO_4$, making the carbonyl group more electrophilic. At the same time, allyl bromides **2** reacted with tin powder to generate the allyl tin bromides **6** *in situ*,[18] which underwent *γ*-addition reaction with intermediates **5** to give intermediates **7**. Finally, the intramolecular oxa-Michael addition and hydrolysis of intermediates **7** afforded the target compounds **3**. It is well known that there are two products (only considering regioselectivity) in the allylation reaction involving allyl organometallic reagents: *α*-addition products and *γ*-addition products. In most cases, the reaction is dominated by *γ*-addition products, and it can be generally considered that the reaction is carried out through a six-membered ring transition state or an acyclic transition state.[18a,19-21] When the reaction was carried out in the presence of additives or Lewis acids (such as transition metal salts) or water, *α*-addition products were produced. For the allylation reaction promoted by tin powder reported in the literature, *γ*-addition products were produced.[18a,20] When the reaction was carried out in the presence of Sn-powder/H_2O,[22] nano-Sn/H_2O,[23-24] and Sn/H_2O/$NaBF_4$,[25] *α*-addition products were produced. In our reaction conditions, no additional metal salt was added, and the reaction was carried out in an organic solvent, and the products are *γ*-addition products.

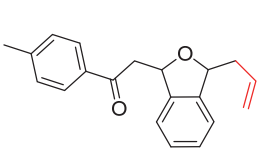
Table 2 Substrate scope of *o*-formyl chalcones[a]



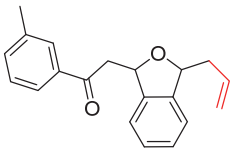
1 2a 3



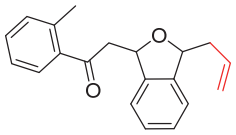
3a
83%, *cis*:*trans* =1:1.1



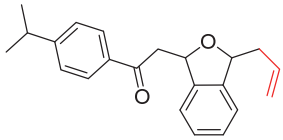
3b
91%, *cis*:*trans* =1:1.1



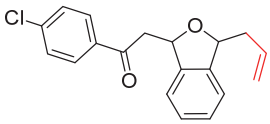
3c
60%, *cis*:*trans* =1:1



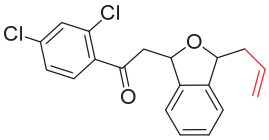
3d
79%, *cis*:*trans* = 1:1.8



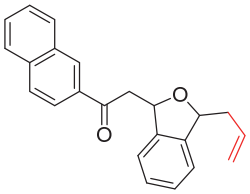
3e
83%, *cis*:*trans* =1.1:1



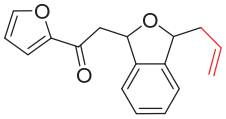
3f
78%, *cis*:*trans* =1.1:1



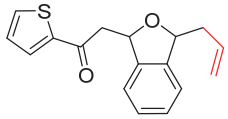
3g
75%, *cis*:*trans* =1.1:1



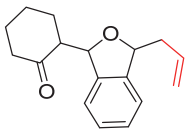
3h
81%, *cis*:*trans* =1:1.1



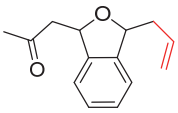
3i
82%, *cis*:*trans* =1.3:1



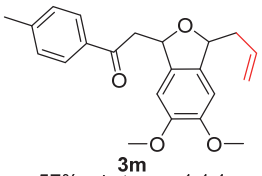
3j
93%, *cis*:*trans* =1.1:1



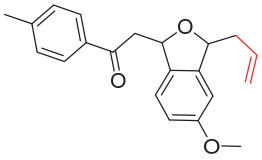
3k
N.R.[b]



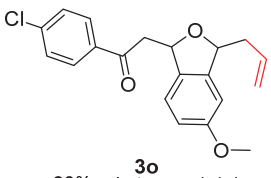
3l
N.R.[b]



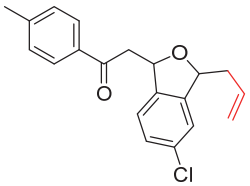
3m
57%, *cis*:*trans* =1:1.1



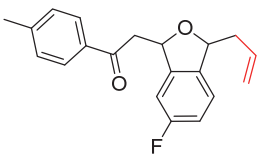
3n
75%, *cis*:*trans* =1:1.1



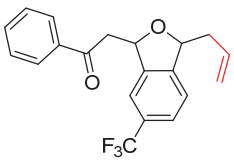
3o
60%, *cis*:*trans* =1.1:1



3p
70%, *cis*:*trans* =1:1.1

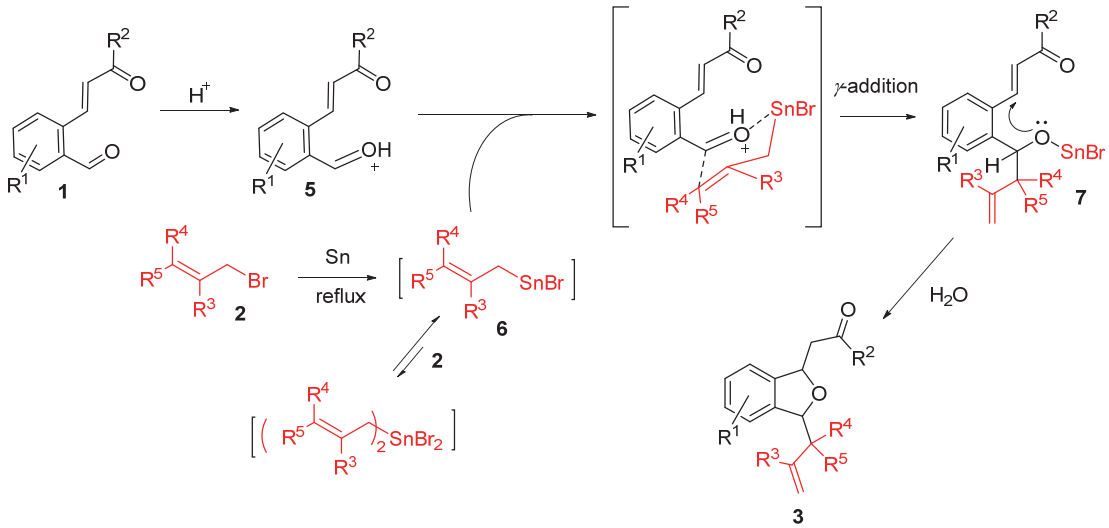


3q
66%, *cis*:*trans* =1:1.1



3r
64%, *cis*:*trans* =1.3:1

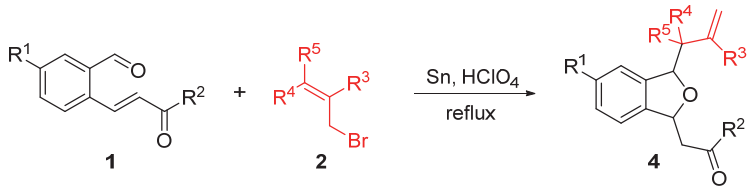
[a]All reactions were carried out by using 0.2 mmol of **1**, 0.4 mmol of **2a**, 0.5 mmol of tin powder, 0.1 mmol of $HClO_4$, EtOH (2 mL), reflux. Combined isolated yield of *cis*- and *trans*-isomers. Molar ratio of *cis*- and *trans*-isomers was determined by ^1H NMR analysis.[10] [b] N.R.=No reacion.

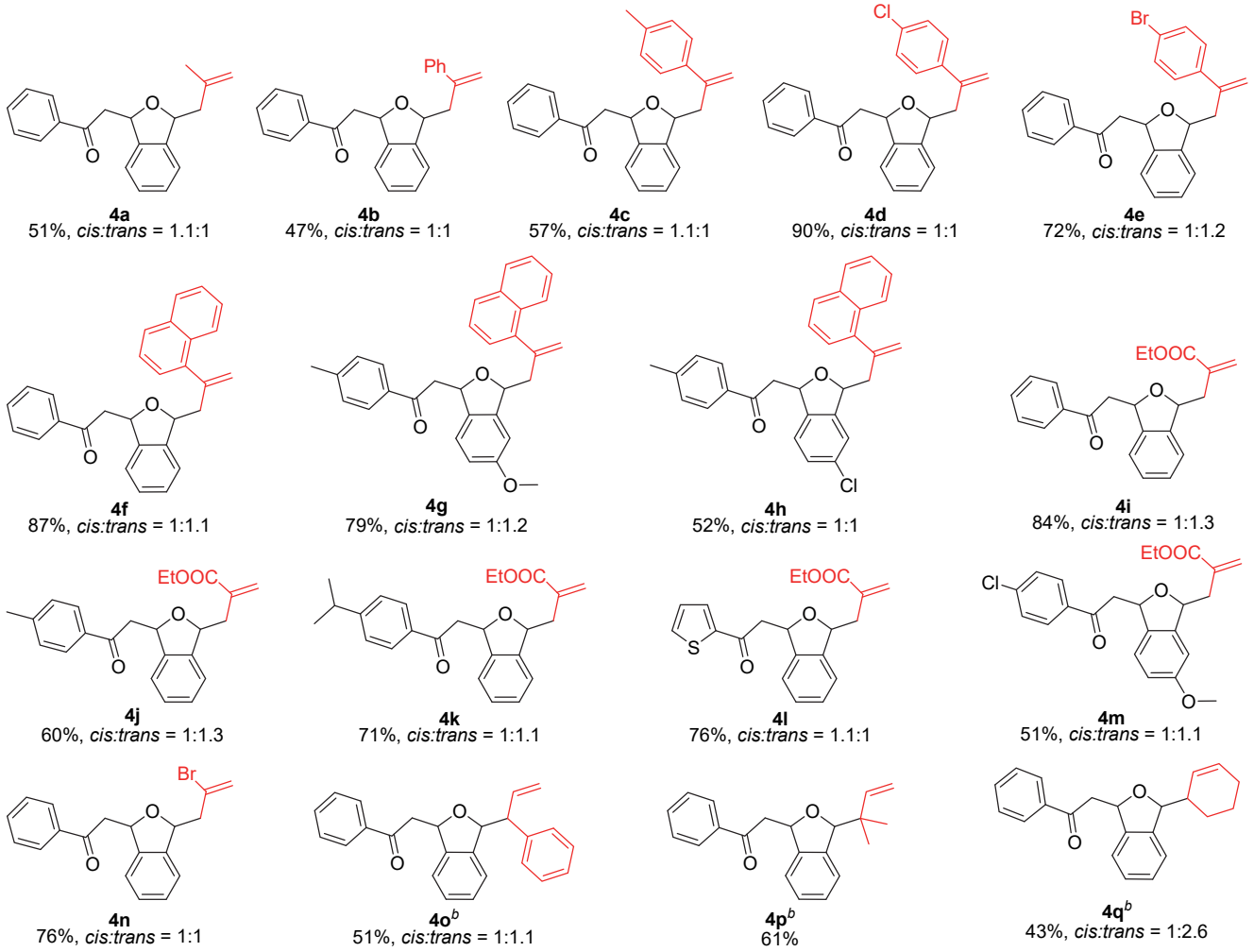


1 5 2 6 7 3

Scheme 2 Proposed mechanistic pathway

Table 3 Substrate scope of allyl bromides and *o*-formyl chalcones[a]





[a] All reactions were carried out by using 0.2 mmol of **1**, 0.4 mmol of **2**, 0.5 mmol of tin powder, 0.1 mmol of $HClO_4$, EtOH (2 mL), reflux. Combined isolated yield of *cis*- and *trans*-isomers. Molar ratio of *cis*- and *trans*-isomers was determined by ^1H NMR analysis.[10] [b] 0.2 mmol of **1a**, 0.4 mmol of **2a**, 0.5 mmol of tin powder, THF (2 mL), reflux.

3 Conclusions

In brief, a tin-powder promoted tandem allylation/oxa-Michael addition reaction of *o*-formyl chalcones with various allyl bromides is developed, which produces 1,3-disubstituted-1,3-dihydroisobenzofuran derivatives in good yields in one-pot process. The method features good tolerance to various functional groups, easy operation, short reaction time and mild reaction conditions. It is further expanded the application of tin-powder promoted allylation reactions in organic synthesis, especially in the synthesis of heterocyclic compounds.

4 Experimental section

4.1 General information

The solvent is distilled in a standard way. Reagents were obtained from commercial suppliers and did not require further purification for use unless otherwise stated. Silica gel column chromatography was performed with silica gel 60 (230～400 mesh). GF254 silica gel was used for thin layer chromatography. Ultraviolet fluorescence display. A Fourier transform ion cyclotron resonance mass spectrometer was used to record high resolution mass spectra. ^1H NMR (400 or 600 MHz), ^{13}C NMR (150 MHz) and ^{19}F NMR (376 MHz) were recorded on a Varian Mercury 400

plus or an Agilent DD2 600 using $CDCl_3$ as solvent. The chemical shift is reported as a δ value relative to the internal TMS (^{1}H NMR δ 0.00), chloroform (^{1}H NMR δ 7.26), and chloroform (^{13}C NMR δ 77.16). *o*-Formyl chalcones **1**[26] and allyl bromides **2b**～**2f**[27] were prepared according to the procedures reported in the literature.

4.2 General procedure for the synthesis of compounds 3 and 4

o-Formyl chalcones **1** (0.2 mmol, 1 equiv.), allyl bromides **2** (0.4 mmol, 2 equiv.), tin powder (0.5 mmol, 2.5 equiv.), $HClO_4$ (0.1 mmol, 0.5 equiv.) and EtOH (2 mL) were put into a dried round-bottom flask (50 mL). The mixture was stirred and refluxed for 1～5 h. The reaction was monitored by thin-layer chromatography (TLC) until the starting material disappeared, and then cooled to room temperature. The saturated $NaHCO_3$ solution (5 mL) was poured into the mixture and the mixture was extracted with EtOAc (5 mL×3). The organic phase was dried with Na_2SO_4, concentrated in vacuo, and purified by column chromatography using petroleum ether/ethyl acetate (*V*∶*V*=15∶1) as the eluent to obtain compounds **3** and **4**

2-(3-Allyl-1,3-dihydroisobenzofuran-1-yl)-1-phenylethan-1-one (**3a**)[10]: Colorless oil, 46.2 mg, 83% yield, *cis*∶*trans*=1∶1.1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 8.02～7.96 (m, 2H), 7.59～7.54 (m, 1H), 7.48～7.43 (m, 2H), 7.32～7.19 (m, 4H), 5.87～5.76 (m, 2H), 5.36 (td, *J*=5.2, 2.8 Hz, 1H), 5.14～5.06 (m, 2H), 3.53 (t, *J*=7.6 Hz, 1H), 3.34 (dd, *J*=8.4, 5.2 Hz, 1H), 2.69～2.49 (m, 2H); δ (minor isomer): 8.02～7.96 (m, 2H), 7.59～7.54 (m, 1H), 7.48～7.43 (m, 2H), 7.32～7.19 (m, 4H), 5.95～5.91 (m, 2H), 5.29 (t, *J*=5.2 Hz, 1H), 5.14～5.06 (m, 2H), 3.58 (t, *J*=7.6 Hz, 1H), 3.30 (dd, *J*=8.4, 5.2 Hz, 1H), 2.69～2.49 (m, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.89, 141.87, 141.63, 137.08, 133.84, 133.19, 128.57, 128.25, 127.70, 127.69, 121.70, 121.37, 117.77, 82.31, 79.32, 45.89, 40.83; δ (minor isomer): 198.00, 141.94, 141.66, 137.16, 134.05, 133.20, 128.56, 128.36, 127.74, 127.70, 121.50, 121.35, 117.71, 82.52, 79.27, 46.52, 40.98. HRMS (ESI) calcd for $C_{19}H_{18}NaO_2$ $[M+Na]^+$ 301.1199, found 301.1194.

2-(3-Allyl-1,3-dihydroisobenzofuran-1-yl)-1-(*p*-tolyl)-ethan-1-one (**3b**)[10]: Colorless oil, 53.2 mg, 91% yield, *cis*∶*trans*=1∶1.1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.91 (d, *J*=8.0 Hz, 2H), 7.31～7.18 (m, 6H), 5.94～5.76 (m, 2H), 5.35 (td, *J*=5.6, 2.4 Hz, 1H), 5.14～5.06 (m, 2H), 3.51 (dd, *J*=8.8, 7.2 Hz, 1H), 3.31 (dd, *J*=7.2, 5.2 Hz, 1H), 2.69～2.49 (m, 2H), 2.41 (s, 3H); δ (minor isomer): 7.87 (d, *J*=8.0 Hz, 2H), 7.31～7.18 (m, 6H), 5.94～5.76 (m, 2H), 5.28 (t, *J*=5.2 Hz, 1H), 5.14～5.06 (m, 2H), 3.55 (dd, *J*=8.8, 7.2 Hz, 1H), 3.26 (dd, *J*=7.2, 5.2 Hz, 1H), 2.69～2.49 (m, 2H), 2.40 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.47, 143.99, 142.06, 141.65, 134.68, 133.88, 129.25, 128.50, 127.69, 127.68, 121.74, 121.35, 117.74, 82.28, 79.39, 46.43, 40.84, 21.63; δ (minor isomer): 197.57, 144.00, 141.99, 141.68, 134.75, 134.09, 129.24, 128.39, 127.68, 127.64, 121.54, 121.34, 117.67, 82.48, 79.34, 45.78, 41.00, 21.63. HRMS (ESI) calcd for $C_{20}H_{20}NaO_2$ $[M+Na]^+$ 315.1356, found 315.1367.

2-(3-Allyl-1,3-dihydroisobenzofuran-1-yl)-1-(*m*-tolyl)-ethan-1-one (**3c**): Colorless oil, 35.1 mg, 60% yield, *cis*∶*trans*=1∶1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.82～7.75 (m, 2H), 7.39～7.19 (m, 6H), 5.94～5.77 (m, 2H), 5.37～5.34 (m, 1H), 5.15～5.06 (m, 2H), 3.53 (t, *J*=7.2 Hz, 1H), 3.32 (dd, *J*=8.4, 5.2 Hz, 1H), 2.69～2.49 (m, 2H), 2.41 (s, 3H); δ (minor isomer): 7.82～7.75 (m, 2H), 7.39～7.19 (m, 6H), 5.94～5.77 (m, 2H), 5.28 (t, *J*=4.8 Hz, 1H), 5.15～5.06 (m, 2H), 3.57 (t, *J*=7.2 Hz, 1H), 3.28 (dd, *J*=8.4, 5.2 Hz, 1H), 2.69～2.49 (m, 2H), 2.40 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 198.18, 142.01, 141.68, 138.36, 137.21, 133.97, 133.95, 128.85, 128.45, 127.70, 127.67, 125.61, 121.73, 121.36, 117.75, 82.50, 79.34, 46.59, 41.00, 21.33; δ (minor isomer): 198.07, 141.96, 141.65, 138.36, 137.13, 134.08, 133.89, 128.77, 128.44, 127.72, 127.70, 125.50, 121.52, 121.36, 117.68, 82.28, 79.29, 45.95, 40.83, 21.33. HRMS (ESI) calcd for $C_{20}H_{20}NaO_2$ $[M+Na]^+$ 315.1356, found 315.1349.

2-(3-Allyl-1,3-dihydroisobenzofuran-1-yl)-1-(*o*-tolyl)-ethan-1-one (**3d**)[10]: Colorless oil, 46.2 mg, 79% yield, *cis*∶*trans*=1∶1.8. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.71～7.64 (m, 1H), 7.39～7.18 (m, 7H), 5.89～5.76 (m, 2H), 5.32～5.26 (m, 1H), 5.14～5.06 (m, 2H), 3.42 (dd, *J*=7.2, 2.0 Hz, 1H), 3.29 (dd, *J*=9.8, 5.2 Hz, 1H), 2.67～2.52 (m, 5H); δ (minor isomer): 7.71～7.64 (m, 1H), 7.39～7.18 (m, 7H), 5.89～5.76 (m, 2H), 5.32～5.26 (m, 1H), 5.14～5.06 (m, 2H), 3.46 (dd, *J*=7.2, 2.0 Hz, 1H), 3.25 (dd, *J*=9.8, 5.2 Hz, 1H), 2.67～2.52 (m, 5H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 201.87, 141.87, 141.67, 138.30, 138.01, 134.05, 131.89, 131.34, 128.80, 127.69, 127.66, 125.57, 121.52, 121.37, 117.67, 82.51, 79.55, 49.39, 41.05, 21.27; δ (minor isomer): 201.83, 141.79, 141.67, 138.25, 137.87, 133.87, 131.88, 131.33, 128.79, 127.66, 127.64, 125.56, 121.36, 121.32, 117.62, 82.24, 79.45, 48.65, 40.81, 21.27. HRMS (ESI) calcd for $C_{20}H_{20}NaO_2$ $[M+Na]^+$ 315.1356, found 315.1351.

2-(3-Allyl-1,3-dihydroisobenzofuran-1-yl)-1-(4-*iso*-propylphenyl)ethan-1-one (**3e**): Colorless oil, 53.1 mg, 83% yield, *cis*∶*trans*=1.1∶1. ^{1}H NMR (600 MHz, $CDCl_3$) δ (major isomer): 7.91 (d, *J*=5.6 Hz, 2H), 7.32～7.18 (m, 6H), 5.93～5.78 (m, 2H), 5.36～5.34 (m, 1H), 5.13～5.06 (m, 2H), 3.52 (dd, *J*=10.2, 7.2 Hz, 1H), 3.30 (dd, *J*=12.0, 5.4 Hz, 1H), 3.00～2.92 (m, 1H), 2.67～2.50 (m, 2H), 1.27 (d, *J*=4.8 Hz, 6H); δ (minor isomer): 7.94 (d, *J*=5.6 Hz, 2H), 7.32～7.18 (m, 6H), 5.93～5.78 (m, 2H), 5.28 (t, *J*=4.8 Hz, 1H), 5.13～5.06 (m, 2H), 3.55 (dd, *J*=10.2, 7.2 Hz, 1H), 3.27 (dd, *J*=12.0, 5.4 Hz, 1H), 3.00～2.92 (m, 1H), 2.67～2.50 (m, 2H), 1.26 (d, *J*=4.8 Hz, 6H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.49, 154.73, 142.00, 141.63, 135.06, 134.09, 128.51, 127.68, 126.66, 121.55, 121.33, 117.74, 82.49, 79.39, 46.45, 40.84, 34.26, 30.91, 23.64; δ (minor isomer):

197.59, 154.72, 142.05, 141.67, 135.00, 133.88, 128.63, 127.63, 126.65, 121.75, 121.33, 117.67, 82.27, 79.34, 45.80, 41.01, 34.25, 30.91, 23.65. HRMS (ESI) calcd for $C_{22}H_{24}NaO_2$ [M+ Na]$^+$ 343.1669, found 343.1672.

2-(3-Allyl-1,3-dihydroisobenzofuran-1-yl)-1-(4-chlorophenyl)ethan-1-one (**3f**)[10]: Colorless oil, 48.7 mg, 78% yield, *cis*∶*trans*=1.1∶1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.95 (d, J=8.8 Hz, 2H), 7.44～7.41 (m, 2H), 7.32～7.19 (m, 4H), 5.91～5.74 (m, 2H), 5.28 (t, J=4.8 Hz, 1H), 5.13～5.05 (m, 2H), 3.48 (t, J=7.2 Hz, 1H), 3.29 (dd, J=7.4, 4.8 Hz, 1H), 2.68～2.48 (m, 2H); δ (minor isomer): 7.91 (d, J=8.8 Hz, 2H), 7.44～7.41 (m, 2H), 7.32～7.19 (m, 4H), 5.91～5.74 (m, 2H), 5.36～5.32 (m, 1H), 5.13～5.05 (m, 2H), 3.52 (t, J=7.6 Hz, 1H), 3.25 (dd, J=7.8, 5.2 Hz, 1H), 2.68～2.48 (m, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 196.82, 141.68, 141.58, 139.67, 135.48, 133.97, 129.69, 128.84, 127.82, 127.73, 121.39, 121.38, 117.73, 82.56, 79.28, 46.42, 40.89; δ (minor isomer): 196.68, 141.60, 141.58, 139.64, 135.39, 133.74, 129.83, 128.86, 127.76, 127.73, 121.58, 121.41, 117.81, 82.37, 79.27, 45.83, 40.80. HRMS (ESI) calcd for $C_{19}H_{17}ClNaO_2$ [M+Na]$^+$ 335.0809, found 335.0802.

2-(3-Allyl-1,3-dihydroisobenzofuran-1-yl)-1-(2,4-dichlorophenyl)ethan-1-one (**3g**): Colorless oil, 51.9 mg, 75% yield, *cis*∶*trans*=1.1∶1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.49 (d, J=8.0 Hz, 1H), 7.43 (d, J=2.0 Hz, 1H), 7.33～7.17 (m, 5H), 5.86～5.70 (m, 2H), 5.30～5.25 (m, 1H), 5.13～5.03 (m, 2H), 3.46～3.31 (m, 2H), 2.64～2.45 (m, 2H); δ (minor isomer): 7.55 (d, J=8.4 Hz, 1H), 7.42 (d, J=2.0 Hz, 1H), 7.33～7.17 (m, 5H), 5.86～5.70 (m, 2H), 5.30～5.25 (m, 1H), 5.13～5.03 (m, 2H), 3.46～3.31 (m, 2H), 2.64～2.45 (m, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 199.58, 141.63, 141.31, 137.48, 137.40, 133.76, 132.12, 130.59, 130.34, 127.82, 127.76, 127.31, 121.44, 121.40, 117.76, 82.40, 79.39, 49.92, 40.76; δ (minor isomer): 199.67, 141.55, 141.23, 137.60, 137.47, 133.92, 132.08, 130.62, 130.32, 127.88, 127.78, 127.33, 121.43, 121.24, 117.70, 82.69, 79.40, 50.73, 41.02. HRMS (ESI) calcd for $C_{19}H_{16}Cl_2NaO_2$ [M+Na]$^+$ 369.0420, found 369.0426.

2-(3-Allyl-1,3-dihydroisobenzofuran-1-yl)-1-(naphthalen-2-yl)ethan-1-one (**3h**): Colorless oil, 53.2 mg, 81% yield, *cis*∶*trans*=1∶1.1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 8.52 (s, 1H), 8.11～8.06 (m, 1H), 7.96～7.86 (m, 3H), 7.62～7.53 (m, 2H), 7.32～7.21 (m, 4H), 6.02～5.79 (m, 2H), 5.41～5.37 (m, 1H), 5.15～5.07 (m, 2H), 3.69 (dd, J=8.8, 7.6 Hz, 1H), 3.47 (t, J=5.6 Hz, 1H), 2.74～2.52 (m, 2H); δ (minor isomer): 8.48 (s, 1H), 8.11～8.06 (m, 1H), 7.96～7.86 (m, 3H), 7.62～7.53 (m, 2H), 7.32～7.21 (m, 4H), 6.02～5.79 (m, 2H), 5.31 (t, J=8.0 Hz, 1H), 5.15～5.07 (m, 2H), 3.73 (dd, J=8.8, 7.6 Hz, 1H), 3.43 (t, J=5.6 Hz, 1H), 2.74～2.52 (m, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.79, 141.99, 141.71, 135.64, 134.54, 133.86, 132.48, 130.18, 129.61, 128.53, 128.44, 127.78, 127.74, 126.77, 123.90, 121.75, 121.41, 117.80, 82.37, 79.46, 45.97, 40.97; δ (minor isomer): 197.92, 141.91, 141.68, 135.66, 134.45, 134.07, 132.50, 130.29, 129.61, 128.53, 128.44, 127.77, 127.73, 126.77, 123.98, 121.55, 121.40, 117.74, 82.55, 79.41, 46.56, 40.85. HRMS (ESI) calcd for $C_{23}H_{20}NaO_2$ [M+Na]$^+$ 351.1356, found 351.1363.

2-(3-Allyl-1,3-dihydroisobenzofuran-1-yl)-1-(furan-2-yl)ethan-1-one (**3i**)[10]: Colorless oil, 44.0 mg, 82% yield, *cis*∶*trans*=1.3∶1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.60 (s, 1H), 7.30～7.19 (m, 5H), 6.55～6.53 (m, 1H), 5.89～5.77 (m, 2H), 5.27 (t, J=8.0 Hz, 1H), 5.13～5.05 (m, 2H), 3.41～3.34 (m, 1H), 3.22～3.12 (m, 1H), 2.68～2.49 (m, 2H); δ (minor isomer): 7.58 (s, 1H), 7.30～7.19 (m, 5H), 6.55～6.53 (m, 1H), 5.89～5.77 (m, 2H), 5.37～5.34 (m, 1H), 5.13～5.05 (m, 2H), 3.41～3.34 (m, 1H), 3.22～3.12 (m, 1H), 2.68～2.49 (m, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 186.66, 152.96, 146.63, 141.63, 141.59, 134.03, 127.78, 127.72, 121.53, 121.40, 117.76, 117.68, 112.30, 82.65, 79.15, 46.46, 41.06; δ (minor isomer): 186.63, 152.90, 146.57, 141.61, 141.59, 133.79, 127.72, 127.70, 121.40, 121.39, 117.86, 117.68, 112.30, 82.33, 79.18, 45.76, 40.74. HRMS (ESI) calcd for $C_{17}H_{16}NaO_3$ [M+Na]$^+$ 291.0992, found 291.0996.

(3-Allyl-1,3-dihydroisobenzofuran-1-yl)-1-(thiophen-2-yl)ethan-1-one (**3j**)[10]: Colorless oil, 52.8 mg, 93% yield, *cis*∶*trans*=1.1∶1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.75～7.64 (m, 2H), 7.32～7.19 (m, 4H), 7.14～7.10 (m, 1H), 5.90～5.76 (m, 2H), 5.28 (t, J=4.0 Hz, 1H), 5.13～5.05 (m, 2H), 3.44 (dd, J=7.6, 2.4 Hz, 1H), 3.26 (dd, J=13.2, 5.2 Hz, 1H), 2.69～2.48 (m, 2H); δ (minor isomer): 7.75～7.64 (m, 2H), 7.32～7.19 (m, 4H), 7.14～7.10 (m, 1H), 5.90～5.76 (m, 2H), 5.38～5.34 (m, 1H), 5.13～5.05 (m, 2H), 3.48 (dd, J=7.6, 2.4 Hz, 1H), 3.22 (dd, J=13.2, 5.2 Hz, 1H), 2.69～2.48 (m, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 190.54, 144.66, 141.63, 141.58, 134.06, 133.97, 132.46, 128.12, 127.81, 127.74, 121.48, 121.39, 117.74, 82.62, 79.42, 47.27, 41.01; δ (minor isomer): 190.64, 144.57, 141.60, 141.57, 134.02, 133.78, 132.68, 128.12, 127.76, 127.73, 121.65, 121.40, 117.80, 82.37, 79.40, 46.62, 40.79. HRMS (ESI) calcd for $C_{17}H_{16}NaO_2S$ [M+Na]$^+$ 307.0763, found 307.0774.

2-(3-Allyl-5,6-dimethoxy-1,3-dihydroisobenzofuran-1-yl)-1-(*p*-tolyl)ethan-1-one (**3m**): Yellow oil, 40.1 mg, 57% yield, *cis*∶*trans*=1∶1.1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.92～7.86 (m, 2H), 7.28～7.25 (m, 2H), 6.76 (d, J=5.6 Hz, 1H), 6.69 (s, 1H), 5.89～5.75 (m, 2H), 5.33～5.29 (m, 1H), 5.15～5.07 (m, 2H), 3.87 (s, 3H), 3.83 (s, 3H), 3.51 (dd, J=9.4, 6.8 Hz, 1H), 3.29～3.24 (m, 1H), 2.65～2.47 (m, 2H), 2.41 (s, 3H); δ (minor isomer): 7.92～7.86 (m, 2H), 7.28～7.25 (m, 2H), 6.76 (d, J=5.6 Hz, 1H), 6.69 (s, 1H), 5.89～5.75 (m, 2H), 5.24 (t, J=5.2Hz, 1H), 5.15～5.07 (m, 2H), 3.88 (s, 3H), 3.84 (s, 3H), 3.55 (dd, J=9.8, 7.2 Hz, 1H), 3.29～3.24 (m, 1H), 2.65～2.47 (m, 2H), 2.42 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.82, 149.13, 149.06, 144.03, 134.71, 133.99, 133.64, 133.23, 129.25, 128.38, 117.69, 104.83, 104.27, 82.39, 79.72, 56.10, 56.06, 46.05, 41.10, 21.63; δ (minor isomer): 197.89, 149.19, 149.11, 144.05, 134.76, 134.22, 133.64, 133.25, 129.24, 128.50, 117.64, 104.65,

104.29, 82.65, 79.66, 56.12, 56.03, 46.83, 41.40, 21.64. HRMS (ESI) calcd for $C_{22}H_{24}NaO_4$ $[M+Na]^+$ 375.1567, found 375.1570.

2-(3-Allyl-5-methoxy-1,3-dihydroisobenzofuran-1-yl)-1-(*p*-tolyl)ethan-1-one (**3n**): Colorless oil, 48.3 mg, 75% yield, *cis*∶*trans*=1∶1.1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.87 (d, J=8.4 Hz, 2H), 7.26 (d, J=8.4 Hz, 2H), 7.12 (d, J=6.4 Hz, 1H), 6.79 (dd, J=5.6, 2.0 Hz, 1H), 6.72 (s, 1H), 5.89～5.74 (m, 2H), 5.32～5.28 (m, 1H), 5.15～5.06 (m, 2H), 3.80 (s, 3H), 3.54～3.46 (m, 1H), 3.28～3.21 (m, 1H), 2.67～2.48 (m, 2H), 2.40 (s, 3H); δ (minor isomer): 7.90 (d, J=8.4 Hz, 2H), 7.24 (d, J=8.4 Hz, 2H), 7.14 (d, J=6.4 Hz, 1H), 6.81 (dd, J=5.6, 2.0 Hz, 1H), 6.72 (s, 1H), 5.89～5.74 (m, 2H), 5.23 (t, J=4.0 Hz, 1H), 5.15～5.06 (m, 2H), 3.80 (s, 3H), 3.54～3.46 (m, 1H), 3.28～3.21 (m, 1H), 2.67～2.48 (m, 2H), 2.41 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.64, 159.69, 143.97, 143.36, 134.69, 134.08, 133.87, 129.24, 128.38, 122.55, 117.77, 113.62, 106.70, 82.10, 79.15, 55.49, 46.01, 40.79, 21.63; δ (minor isomer): 197.73, 159.69, 143.98, 143.38, 134.76, 134.16, 134.08, 129.23, 128.49, 122.35, 117.70, 113.65, 106.70, 82.29, 79.10, 55.51, 46.67, 40.97, 21.63. HRMS (ESI) calcd for $C_{21}H_{22}NaO_3$ $[M+Na]^+$ 345.1461, found 345.1448.

2-(3-Allyl-5-methoxy-1,3-dihydroisobenzofuran-1-yl)-1-(4-chlorophenyl)ethan-1-one (**3o**): Colorless oil, 41.1 mg, 60% yield, *cis*∶*trans*=1.1∶1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.94 (d, J=8.4 Hz, 2H), 7.43 (d, J=8.4 Hz, 2H), 7.13 (d, J=8.4 Hz, 1H), 6.83～6.80 (m, 1H), 6.71 (s, 1H), 5.87～5.67 (m, 2H), 5.23 (t, J=4.0 Hz, 1H), 5.14～5.07 (m, 2H), 3.81 (s, 3H), 3.51～3.44 (m, 1H), 3.27～3.21 (m, 1H), 2.66～2.47 (m, 2H); δ (minor isomer): 7.90 (d, J=8.4 Hz, 2H), 7.42 (d, J=8.4 Hz, 2H), 7.12 (d, J=8.4 Hz, 1H), 6.83～6.80 (m, 1H), 6.71 (s, 1H), 5.87～5.67 (m, 2H), 5.30～5.27 (m, 1H), 5.14～5.07 (m, 2H), 3.80 (s, 3H), 3.51～3.44 (m, 1H), 3.27～3.21 (m, 1H), 2.66～2.47 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.00, 159.86, 143.32, 139.66, 135.53, 134.00, 133.75, 129.85, 128.84, 122.23, 117.76, 113.74, 106.73, 82.38, 79.07, 55.52, 46.67, 40.88; δ (minor isomer): 196.87, 159.77, 143.33, 139.63, 135.45, 133.79, 133.70, 129.70, 128.87, 122.42, 117.84, 113.71, 106.75, 82.21, 79.07, 55.50, 46.07, 40.76. HRMS (ESI) calcd for $C_{20}H_{19}ClNaO_3$ $[M+Na]^+$ 365.0915, found 365.0923.

2-(3-Allyl-5-chloro-1,3-dihydroisobenzofuran-1-yl)-1-(*p*-tolyl)ethan-1-one (**3p**): Colorless oil, 45.7 mg, 70% yield, *cis*∶*trans*=1∶1.1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.89 (d, J=8.4 Hz, 2H), 7.27～7.16 (m, 5H), 5.88～5.74 (m, 2H), 5.32～5.29 (m, 1H), 5.15～5.09 (m, 2H), 3.57～3.49 (m, 1H), 3.30～3.23 (m, 1H), 2.66～2.48 (m, 2H), 2.41 (s, 3H); δ (minor isomer): 7.86 (d, J=8.4 Hz, 2H), 7.27～7.16 (m, 5H), 5.88～5.74 (m, 2H), 5.23 (t, J=4.0 Hz, 1H), 5.15～5.09 (m, 2H), 3.57～3.49 (m, 1H), 3.30～3.23 (m, 1H), 2.66～2.48 (m, 2H), 2.40 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.24, 144.19, 143.78, 140.57, 134.48, 133.55, 133.34, 129.31, 128.44, 127.95, 122.90, 121.66, 118.20, 82.01, 79.12, 45.54, 40.61, 21.65; δ (minor isomer): 197.31, 144.18, 143.74, 140.66, 134.54, 133.60, 133.54, 129.29, 128.34, 127.94, 123.10, 121.66, 118.11, 81.88, 79.02, 46.18, 40.69, 21.64. HRMS (ESI) calcd for $C_{20}H_{19}ClNaO_2$ $[M+Na]^+$ 349.0966, found 349.0976.

2-(3-Allyl-6-fluoro-1,3-dihydroisobenzofuran-1-yl)-1-(*p*-tolyl)ethan-1-one (**3q**): Colorless oil, 40.9 mg, 66% yield, *cis*∶*trans*=1∶1.1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.90 (d, J=8.8 Hz, 2H), 7.27 (d, J=8.0 Hz, 2H), 7.14～7.11 (m, 1H), 6.99～6.94 (m, 2H), 5.90～5.75 (m, 2H), 5.31 (t, J=4.2 Hz, 1H), 5.13～5.07 (m, 2H), 3.53 (dd, J=8.8, 6.8 Hz, 1H), 3.29 (dd, J=6.4, 3.6 Hz, 1H), 2.66～2.47 (m, 2H), 2.42 (s, 3H); δ (minor isomer): 7.87 (d, J=8.0 Hz, 2H), 7.26 (d, J=8.0 Hz, 2H), 7.14～7.11 (m, 1H), 6.99～6.94 (m, 2H), 5.90～5.75 (m, 2H), 5.24 (t, J=4.2 Hz, 1H), 5.13～5.07 (m, 2H), 3.57 (dd, J=8.8, 6.8 Hz, 1H), 3.25 (dd, J=6.4, 3.6 Hz, 1H), 2.66～2.47 (m, 2H), 2.41 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.15, 162.72 (d, $J_{C\text{-}F}$=243.0 Hz), 144.35 (d, $J_{C\text{-}F}$=7.5 Hz), 144.16, 137.07 (d, $J_{C\text{-}F}$=3.0 Hz), 134.50, 133.55, 129.28, 128.31, 122.51, 117.96, 114.89 (d, $J_{C\text{-}F}$=7.5 Hz), 109.18 (d, $J_{C\text{-}F}$=24.0 Hz), 81.83, 79.02 (d, $J_{C\text{-}F}$=3.0 Hz), 45.47, 40.98, 21.62; δ (minor isomer): 197.21, 162.68 (d, $J_{C\text{-}F}$=243.0 Hz), 144.28 (d, $J_{C\text{-}F}$=9.0 Hz), 144.15, 137.11 (d, $J_{C\text{-}F}$=3.0 Hz), 134.44, 133.76, 129.27, 128.41, 122.45, 117.88, 114.73 (d, $J_{C\text{-}F}$=6.0 Hz), 108.99 (d, $J_{C\text{-}F}$=24.0 Hz), 81.99, 78.88 (d, $J_{C\text{-}F}$=1.5 Hz), 46.11, 40.88, 21.63. ^{19}F NMR (376 MHz, $CDCl_3$) δ: −115.48～−115.55 (m); HRMS (ESI) calcd for $C_{20}H_{19}FNaO_2$ $[M+Na]^+$ 333.1261, found 333.1265.

2-(3-Allyl-5-(trifluoromethyl)-1,3-dihydroisobenzofuran-1-yl)-1-phenylethan-1-one (**3r**)[10]: Colorless oil, 44.3 mg, 64% yield, *cis*∶*trans*=1.3∶1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 8.01～7.96 (m, 2H), 7.61～7.52 (m, 2H), 7.50～7.45 (m, 3H), 7.38 (t, J=8.8 Hz, 1H), 5.98～5.75 (m, 2H), 5.31 (t, J=5.6 Hz, 1H), 5.16～5.11 (m, 2H), 3.58 (t, J=6.8 Hz, 1H), 3.38～3.30 (m, 1H), 2.71～2.52 (m, 2H); δ (minor isomer): 8.01～7.96 (m, 2H), 7.61～7.52 (m, 2H), 7.50～7.45 (m, 3H), 7.38 (t, J=8.8 Hz, 1H), 5.98～5.75 (m, 2H), 5.40～5.37 (m, 1H), 5.16～5.11 (m, 2H), 3.62 (t, J=6.8 Hz, 1H), 3.38～3.30 (m, 1H), 2.71～2.52 (m, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.49, 146.00 (d, $J_{C\text{-}F}$=1.5 Hz), 142.65, 136.88, 133.42, 133.36, 130.50 (d, $J_{C\text{-}F}$=10.5 Hz), 128.65, 128.30, 125.12 (q, $J_{C\text{-}F}$=3.0 Hz), 124.12 (q, $J_{C\text{-}F}$=270.0 Hz), 122.22, 118.52 (q, $J_{C\text{-}F}$=7.5 Hz), 118.29, 82.18, 79.05, 46.06, 40.68; δ (minor isomer): 197.43, 145.92 (d, $J_{C\text{-}F}$=1.5 Hz), 142.61, 136.82, 133.41, 133.15, 130.29 (d, $J_{C\text{-}F}$=10.5 Hz), 128.65, 128.19, 125.12 (q, $J_{C\text{-}F}$=3.0 Hz), 124.12 (q, $J_{C\text{-}F}$=270.0 Hz), 122.41, 118.52 (q, $J_{C\text{-}F}$=7.5 Hz), 118.38, 82.06, 79.14, 45.43, 40.61. ^{19}F NMR (376 MHz, $CDCl_3$) δ: −62.10 (s), −62.11 (s); HRMS (ESI) calcd for $C_{20}H_{17}F_3NaO_2$ $[M+Na]^+$ 369.10729, found 369.10731.

2-(3-(2-Methylallyl)-1,3-dihydroisobenzofuran-1-yl)-1-phenylethan-1-one (**4a**): Colorless oil, 29.8 mg, 51% yield, *cis*∶*trans*=1.1∶1. ^{1}H NMR (600 MHz, $CDCl_3$) δ (major

isomer): 8.01～7.97 (m, 2H), 7.58～7.54 (m, 1H), 7.48～7.44 (m, 2H), 7.30～7.18 (m, 4H), 5.83 (t, *J*=6.0 Hz, 1H), 5.34 (t, *J*=6.0 Hz, 1H), 4.80 (s, 2H), 3.56 (dd, *J*=11.2, 4.4 Hz, 1H), 3.35 (dd, *J*=10.8, 3.6 Hz, 1H), 2.57～2.45 (m, 2H), 1.81 (s, 3H); *δ* (minor isomer): 8.01～7.97 (m, 2H), 7.58～7.54 (m, 1H), 7.48～7.44 (m, 2H), 7.30～7.18 (m, 4H), 5.94～5.92 (m, 1H), 5.44～5.42 (m, 1H), 4.87 (s, 2H), 3.58 (dd, *J*=11.2, 4.4 Hz, 1H), 3.32 (dd, *J*=10.8, 3.6 Hz, 1H), 2.57～2.45 (m, 2H), 1.82 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) *δ* (major isomer): 197.98, 142.28, 142.00, 141.83, 137.17, 133.17, 128.55, 128.33, 127.69, 127.65, 121.54, 121.46, 113.14, 81.40, 79.23, 46.73, 45.67, 23.05; *δ* (minor isomer): 197.94, 142.08, 141.99, 141.77, 137.11, 133.15, 128.55, 128.25, 127.67, 127.61, 121.73, 121.45, 113.13, 81.20, 79.03, 45.83, 44.75, 23.03. HRMS (ESI) calcd for $C_{20}H_{20}NaO_2$ $[M+Na]^+$ 315.1356, found 315.1356.

1-Phenyl-2-(3-(2-phenylallyl)-1,3-dihydroisobenzofuran-1-yl)ethan-1-one (**4b**): Colorless oil, 33.3 mg, 47% yield, *cis*∶*trans*=1∶1. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* (major isomer): 7.96～7.93 (m, 2H), 7.59～7.35 (m, 6H), 7.29～7.13 (m, 6H), 5.91～5.87 (m, 1H), 5.38 (d, *J*=2.8 Hz, 2H), 5.36～5.29 (m, 1H), 3.52～3.40 (m, 1H), 3.29～3.23 (m, 1H), 2.99～2.85 (m, 2H); *δ* (minor isomer): 7.96～7.93 (m, 2H), 7.59～7.35 (m, 6H), 7.29～7.13 (m, 6H), 5.79 (t, *J*=6.0 Hz, 1H), 5.36～5.29 (m, 1H), 5.16 (d, *J*=5.6 Hz, 2H), 3.52～3.40 (m, 1H), 3.29～3.23 (m, 1H), 2.99～2.85 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) *δ* (major isomer): 197.87, 143.34, 141.75, 141.64, 139.50, 137.02, 133.26, 133.20, 128.57, 128.37, 128.24, 127.78, 127.64, 127.60, 121.64, 121.50, 115.96, 81.45, 79.12, 46.42, 42.87; *δ* (minor isomer): 197.73, 143.33, 141.83, 141.60, 139.43, 137.03, 133.24, 133.17, 128.54, 128.44, 128.23, 127.77, 127.60, 127.57, 121.67, 121.63, 116.00, 81.00, 79.10, 45.83, 42.48. HRMS (ESI) calcd for $C_{25}H_{23}O_2$ $[M+H]^+$ 355.16926, found 355.16956.

1-Phenyl-2-(3-(2-(*p*-tolyl)allyl)-1,3-dihydroisobenzofuran-1-yl)ethan-1-one (**4c**): Colorless oil, 42.0 mg, 57% yield, *cis*∶*trans*=1.1∶1. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* (major isomer): 7.98～7.93 (m, 2H), 7.59～7.53 (m, 1H), 7.48～7.42 (m, 2H), 7.39～7.35 (m, 2H), 7.27～7.09 (m, 6H), 5.79 (t, *J*=6.0 Hz, 1H), 5.39～5.30 (m, 2H), 5.10 (s, 1H), 3.53～3.44 (m, 1H), 3.32～3.23 (m, 1H), 3.09～2.82 (m, 2H), 2.30 (s, 3H); *δ* (minor isomer): 7.98～7.93 (m, 2H), 7.59～7.53 (m, 1H), 7.48～7.42 (m, 2H), 7.39～7.35 (m, 2H), 7.27～7.09 (m, 6H), 5.94～5.90 (m, 1H), 5.39～5.30 (m, 2H), 5.10 (s, 1H), 3.53～3.44 (m, 1H), 3.32～3.23 (m, 1H), 3.09～2.82 (m, 2H), 2.35 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) *δ* (major isomer): 197.96, 144.09, 141.93, 141.85, 137.94, 137.27, 137.12, 133.14, 129.01, 128.54, 128.25, 127.65, 127.54, 126.17, 121.81, 121.47, 114.69, 81.36, 79.09, 46.68, 43.31, 21.05; *δ* (minor isomer): 197.89, 144.05, 141.99, 141.79, 137.91, 137.27, 137.09, 133.14, 129.07, 128.54, 128.31, 127.66, 127.48, 126.13, 121.82, 121.63, 114.62, 80.89, 78.97, 45.92, 42.69, 21.10. HRMS (ESI) calcd for $C_{26}H_{24}NaO_2$ $[M+Na]^+$ 391.16685, found 391.16654.

2-(3-(2-(4-Chlorophenyl)allyl)-1,3-dihydroisobenzofuran-1-yl)-1-phenylethan-1-one (**4d**): Colorless oil, 69.8 mg, 90% yield, *cis*∶*trans*=1∶1. ^{1}H NMR (600 MHz, $CDCl_3$) *δ* (major isomer): 7.95～7.93 (m, 2H), 7.58～7.55 (m, 1H), 7.46～7.42 (m, 2H), 7.38～7.34 (m, 2H), 7.29～7.12 (m, 5H), 5.89～5.87 (m, 1H), 5.38～5.28 (m, 2H), 5.16 (d, *J*=6.6 Hz, 1H), 3.48 (dd, *J*=16.2, 6.6 Hz, 1H), 3.27 (dd, *J*=6.0, 4.2 Hz, 1H), 3.02～2.86 (m, 2H); minor isomer: 7.95～7.93 (m, 2H), 7.58～7.55 (m, 1H), 7.46～7.42 (m, 2H), 7.38～7.34 (m, 2H), 7.29～7.12 (m, 5H), 5.78 (t, *J*=6.6 Hz, 1H), 5.38～5.28 (m, 2H), 5.16 (d, *J*=6.6 Hz, 1H), 3.42 (dd, *J*=16.8, 6.6 Hz, 1H), 3.24 (dd, *J*=6.0, 4.2 Hz, 1H), 3.02～2.86 (m, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) *δ* (major isomer): 197.87, 143.34, 141.76, 141.61, 139.52, 137.03, 133.25, 133.21, 128.58, 128.45, 128.23, 127.79, 127.61, 127.58, 121.65, 121.64, 116.01, 81.46, 79.13, 45.84, 42.49; *δ* (minor isomer): 197.74, 143.35, 141.84, 141.65, 139.44, 137.04, 133.27, 133.18, 128.55, 128.38, 128.25, 127.78, 127.65, 127.61, 121.68, 121.51, 115.97, 81.01, 79.11, 46.43, 42.88. HRMS (ESI) calcd for $C_{25}H_{20}ClO_2$ $[M-H]^-$ 387.11463, found 387.11468.

2-(3-(2-(4-Bromophenyl)allyl)-1,3-dihydroisobenzofuran-1-yl)-1-phenylethan-1-one (**4e**): Colorless oil, 62.2 mg, 72% yield, *cis*∶*trans*=1∶1.2. ^{1}H NMR (600 MHz, $CDCl_3$) *δ* (major isomer): 7.96～7.93 (m, 2H), 7.59～7.54 (m, 1H), 7.49～7.38 (m, 4H), 7.32～7.09 (m, 6H), 5.78 (t, *J*=6.4 Hz, 1H), 5.38～5.29 (m, 2H), 5.17 (dd, *J*=7.8, 1.2 Hz, 1H), 3.52～3.40 (m, 1H), 3.28 (dd, *J*=8.4, 5.4 Hz, 1H), 3.03～2.85 (m, 2H); *δ* (minor isomer): 7.96～7.93 (m, 2H), 7.59～7.54 (m, 1H), 7.49～7.38 (m, 4H), 7.32～7.09 (m, 6H), 5.90～5.86 (m, 1H), 5.38～5.29 (m, 2H), 5.17 (dd, *J*=7.8, 1.2 Hz, 1H), 3.52～3.40 (m, 1H), 3.24 (dd, *J*=8.4, 6.0 Hz, 1H), 3.03～2.85 (m, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) *δ* (major isomer): 197.88, 143.41, 141.84, 141.63, 140.00, 137.02, 133.21, 131.33, 128.55, 128.25, 127.99, 127.78, 127.62, 121.64, 121.63, 121.44, 116.03, 81.46, 79.13, 46.42, 42.82; *δ* (minor isomer): 197.74, 143.39, 141.75, 141.59, 139.91, 137.03, 133.18, 131.41, 128.60, 128.23, 127.93, 127.80, 127.58, 121.68, 121.52, 121.42, 116.08, 81.00, 79.11, 45.83, 42.44. HRMS (ESI) calcd for $C_{25}H_{21}BrNaO_2$ $[M+Na]^+$ 455.0617, found 455.06190.

2-(3-(2-(Naphthalen-1-yl)allyl)-1,3-dihydroisobenzofuran-1-yl)-1-phenylethan-1-one (**4f**): Colorless oil, 70.3 mg, 87% yield, *cis*∶*trans*=1∶1.1. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* (major isomer): 8.07～7.93 (m, 3H), 7.84～7.71 (m, 2H), 7.60～7.09 (m, 11H), 5.93～5.89 (m, 1H), 5.55～5.53 (m, 1H), 5.29～5.21 (m, 2H), 3.50 (dd, *J*=16.4, 6.4 Hz, 1H), 3.23 (dd, *J*=15.2, 6.0 Hz, 1H), 3.13～2.91 (m, 2H); *δ* (minor isomer): 8.07～7.93 (m, 3H), 7.84～7.71 (m, 2H), 7.60～7.09 (m, 11H), 5.75 (t, *J*=8.4 Hz, 1H), 5.55～5.53 (m, 1H), 5.29～5.21 (m, 2H), 3.38 (dd, *J*=16.4, 6.8 Hz, 1H), 3.19 (dd, *J*=14.8, 5.6 Hz, 1H), 3.13～2.91 (m, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) *δ* (major isomer): 198.05, 144.75, 142.04, 141.84, 140.81, 137.17, 133.68, 133.10, 131.25, 128.51, 128.34, 128.18, 127.64,

127.57, 127.27, 125.86, 125.79, 125.61, 125.38, 125.18, 121.70, 121.37, 118.48, 80.76, 79.19, 46.46, 45.77; δ (minor isomer): 197.95, 144.83, 141.94, 141.89, 140.72, 137.15, 133.68, 133.13, 131.19, 128.52, 128.27, 128.22, 127.65, 127.60, 127.27, 125.80, 125.76, 125.58, 125.46, 125.21, 121.53, 121.34, 118.33, 81.24, 79.08, 46.12, 45.40. HRMS (ESI) calcd for $C_{29}H_{24}NaO_2$ $[M+Na]^+$ 427.1669, found 427.1651.

2-(5-Methoxy-3-(2-(naphthalen-1-yl)allyl)-1,3-dihydroisobenzofuran-1-yl)-1-(*p*-tolyl)ethan-1-one (**4g**): Colorless oil, 70.8 mg, 79% yield, *cis*∶*trans*=1∶1.2. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 8.07～7.99 (m, 1H), 7.86～7.81 (m, 3H), 7.75～7.71 (m, 1H), 7.46～7.36 (m, 3H), 7.30～7.20 (m, 3H), 7.09 (t, J=8.0 Hz, 1H), 6.77～6.72 (m, 1H), 6.55 (d, J=2.0 Hz, 1H), 5.86～5.83 (m, 1H), 5.56 (s, 1H), 5.25～5.18 (m, 2H), 3.67 (s, 3H), 3.45 (dd, J=16.0, 6.0 Hz, 1H), 3.19 (dd, J=8.8, 6.4 Hz, 1H), 3.09～2.92 (m, 2H), 2.39 (s, 3H); δ (minor isomer): 8.07～7.99 (m, 1H), 7.86～7.81 (m, 3H), 7.75～7.71 (m, 1H), 7.46～7.36 (m, 3H), 7.30～7.20 (m, 3H), 7.09 (t, J=8.0 Hz, 1H), 6.77～6.72 (m, 1H), 6.60 (d, J=2.0 Hz, 1H), 5.69 (t, J=6.4 Hz, 1H), 5.54 (s, 1H), 5.25～5.18 (m, 2H), 3.69 (s, 3H), 3.38 (dd, J=16.4, 6.4 Hz, 1H), 3.15 (dd, J=8.8, 6.4 Hz, 1H), 3.09～2.92 (m, 2H), 2.41 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.79, 159.55, 144.69, 143.85, 143.43, 140.74, 134.74, 134.02, 133.67, 131.14, 129.18, 128.39, 128.18, 127.24, 125.85, 125.78, 125.59, 125.38, 125.17, 122.51, 118.60, 113.86, 106.44, 80.70, 79.04, 55.39, 46.63, 45.90, 21.61; δ (minor isomer): 197.70, 159.61, 144.80, 143.90, 143.65, 140.83, 134.74, 134.06, 133.68, 131.18, 129.18, 128.46, 128.22, 127.26, 125.79, 125.77, 125.59, 125.48, 125.21, 122.34, 118.41, 113.86, 106.48, 81.12, 78.92, 55.42, 45.99, 45.23, 21.63. HRMS (ESI) calcd for $C_{31}H_{28}NaO_3$ $[M+Na]^+$ 471.1931, found 471.1925.

2-(5-Chloro-3-(2-(naphthalen-1-yl)allyl)-1,3-dihydroisobenzofuran-1-yl)-1-(*p*-tolyl)ethan-1-one (**4h**): Colorless oil, 47.0 mg, 52% yield, *cis*∶*trans*=1∶1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.97 (d, J=8.0 Hz, 1H), 7.83～7.80 (m, 3H), 7.73 (t, J=7.6 Hz, 1H), 7.46～7.35 (m, 3H), 7.28～7.08 (m, 5H), 7.00 (s, 1H), 5.86～5.82 (m, 1H), 5.55 (s, 1H), 5.23～5.15 (m, 2H), 3.46 (dd, J=16.4, 6.0 Hz, 1H), 3.20～3.07 (m, 1H), 3.05～2.89 (m, 2H), 2.38 (s, 3H); δ (minor isomer): 8.05～8.02 (m, 1H), 7.83～7.80 (m, 3H), 7.73 (t, J=7.6 Hz, 1H), 7.46～7.35 (m, 3H), 7.28～7.08 (m, 5H), 7.06 (s, 1H), 5.68 (t, J=6.0 Hz, 1H), 5.52 (s, 1H), 5.23～5.15 (m, 2H), 3.36 (dd, J=16.8, 6.0 Hz, 1H), 3.20～3.07 (m, 1H), 3.05～2.89 (m, 2H), 2.40 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.33, 144.31, 144.06, 144.01, 140.58, 140.49, 133.66, 133.39, 131.07, 129.20, 128.38, 128.20, 127.81, 127.38, 125.83, 125.65, 125.61, 125.44, 125.16, 122.85, 121.65, 118.75, 80.75, 78.80, 46.03, 45.38, 21.60; δ (minor isomer): 197.23, 144.42, 144.03, 143.78, 140.51, 140.37, 134.48, 133.34, 131.11, 129.21, 128.30, 128.25, 127.79, 127.38, 125.81, 125.70, 125.61, 125.33, 125.12, 123.02, 121.61, 118.57, 80.38, 78.93, 45.73, 45.10, 21.62. HRMS (ESI) calcd for $C_{30}H_{25}ClNaO_2$ $[M+Na]^+$ 475.1435, found 475.1433.

Ethyl 2-((3-(2-oxo-2-phenylethyl)-1,3-dihydroisobenzofuran-1-yl)methyl) acrylate (**4i**): Colorless oil, 58.8 mg, 84% yield, *cis*∶*trans*=1∶1.3. ^{1}H NMR (600 MHz, $CDCl_3$) δ (major isomer): 8.00～7.95 (m, 2H), 7.58～7.54 (m, 1H), 7.48～7.43 (m, 2H), 7.30～7.19 (m, 4H), 6.25 (d, J=1.2 Hz, 1H), 5.92～5.90 (m, 1H), 5.67 (d, J=1.2 Hz, 1H), 5.47～5.44 (m, 1H), 4.20～4.12 (m, 2H), 3.52 (dd, J=6.6, 2.4 Hz, 1H), 3.30 (dd, J=16.8, 6.0 Hz, 1H), 2.98～2.81 (m, 1H), 2.69～2.62 (m, 1H), 1.27 (t, J=6.6 Hz, 3H); δ (minor isomer): 8.00～7.95 (m, 2H), 7.58～7.54 (m, 1H), 7.48～7.43 (m, 2H), 7.30～7.19 (m, 4H), 6.21 (d, J=1.2 Hz, 1H), 5.83 (t, J=6.0 Hz, 1H), 5.58 (d, J=1.2 Hz, 1H), 5.39～5.37 (m, 1H), 4.20～4.12 (m, 2H), 3.55 (dd, J=6.6, 2.4 Hz, 1H), 3.35 (dd, J=16.8, 6.0 Hz, 1H), 2.98～2.81 (m, 1H), 2.69～2.62 (m, 1H), 1.26 (t, J=6.6 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 196.85, 166.10, 140.76, 140.46, 136.06, 135.64, 132.16, 127.55, 127.22, 126.80, 126.70, 126.63, 120.57, 120.51, 80.37, 78.07, 59.70, 44.84, 37.95, 13.18; δ (minor isomer): 196.82, 166.11, 140.77, 140.52, 136.13, 135.66, 132.18, 127.57, 127.29, 126.83, 126.74, 126.53, 120.68, 120.53, 80.64, 78.41, 59.70, 45.64, 38.48, 13.17. HRMS (ESI) calcd for $C_{22}H_{22}NaO_4$ $[M+Na]^+$ 373.1410, found 373.1402.

Ethyl 2-((3-(2-oxo-2-(*p*-tolyl)ethyl)-1,3-dihydroisobenzofuran-1-yl)methyl)acrylate (**4j**): Colorless oil, 43.7 mg, 60% yield, *cis*∶*trans*=1∶1.3. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.91～7.85 (m, 2H), 7.29～7.19 (m, 6H), 6.26 (t, J=4.0 Hz, 1H), 5.91 (t, J=8.0 Hz, 1H), 5.68 (s, 1H), 5.48～5.45 (m, 1H), 4.22～4.13 (m, 2H), 3.54～3.48 (m, 1H), 3.35～3.25 (m, 1H), 2.99～2.81 (m, 1H), 2.71～2.63 (m, 1H), 2.41 (s, 3H), 1.30～1.25 (m, 3H); δ (minor isomer): 7.91～7.85 (m, 2H), 7.29～7.19 (m, 6H), 6.22 (t, J=4.0 Hz, 1H), 5.83 (t, J=8.0 Hz, 1H), 5.60 (s, 1H), 5.40～5.37 (m, 1H), 4.22～4.13 (m, 2H), 3.54～3.48 (m, 1H), 3.35～3.25 (m, 1H), 2.99～2.81 (m, 1H), 2.71～2.63 (m, 1H), 2.40 (s, 3H), 1.30～1.25 (m, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.43, 167.08, 143.96, 141.86, 141.45, 136.65, 134.69, 129.21, 128.33, 127.79, 127.76, 127.73, 121.70, 121.53, 81.32, 79.11, 60.68, 45.71, 38.93, 21.60, 14.17; δ (minor isomer): 197.39, 167.10, 143.99, 141.84, 141.51, 136.65, 134.63, 129.23, 128.41, 127.64, 127.57, 127.53, 121.53, 121.49, 81.58, 79.44, 60.68, 46.53, 39.48, 21.61, 14.16. HRMS (ESI) calcd for $C_{23}H_{24}NaO_4$ $[M+Na]^+$ 387.1567, found 387.1568.

Ethyl 2-((3-(2-(4-isopropylphenyl)-2-oxoethyl)-1,3-dihydroisobenzofuran-1-yl)methyl)acrylate (**4k**): Colorless oil, 55.7 mg, 71% yield, *cis*∶*trans*=1∶1.1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.95～7.89 (m, 2H), 7.33～7.19 (m, 6H), 6.22 (s, 1H), 5.84～5.82 (m, 1H), 5.59 (s, 1H), 5.40～5.37 (m, 1H), 4.22～4.13 (m, 2H), 3.55～3.49 (m, 1H), 3.35～3.25 (m, 1H), 3.00～2.81 (m, 2H), 2.71～2.62 (m, 1H), 1.30～1.25 (m, 9H); δ (minor isomer): 7.95～7.89 (m, 2H), 7.33～7.19 (m, 6H), 6.26 (s,

1H), 5.93～5.90 (m, 1H), 5.68 (s, 1H), 5.48～5.45 (m, 1H), 4.22～4.13 (m, 2H), 3.55～3.49 (m, 1H), 3.35～3.25 (m, 1H), 3.00～2.81 (m, 2H), 2.71～2.62 (m, 1H), 1.30～1.25 (m, 9H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.48, 167.12, 154.72, 141.91, 141.55, 136.68, 135.07, 128.49, 127.79, 127.66, 127.59, 126.67, 121.57, 121.55, 81.61, 79.49, 60.69, 45.75, 38.95, 34.23, 23.64, 14.17; δ (minor isomer): 197.44, 167.12, 154.74, 141.91, 141.49, 136.68, 135.01, 128.58, 127.82, 127.74, 127.55, 126.65, 121.75, 121.51, 81.34, 79.14, 60.69, 46.56, 39.50, 34.25, 23.63, 14.18. HRMS (ESI) calcd for $C_{25}H_{28}NaO_4$ $[M+Na]^+$ 415.1880, found 415.1875.

Ethyl 2-((3-(2-oxo-2-(thiophen-2-yl)ethyl)-1,3-dihydroisobenzofuran-1-yl)methyl)acrylate (**4l**): Yellow oil, 54.1 mg, 76% yield, *cis*∶*trans*=1.1∶1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.75～7.69 (m, 1H), 7.67～7.64 (m, 1H), 7.32～7.19 (m, 4H), 7.14～7.10 (m, 1H), 6.22 (d, J=1.6 Hz, 1H), 5.79 (t, J=6.4 Hz, 1H), 5.60 (d, J=1.2 Hz, 1H), 5.39～5.37 (m, 1H), 4.21～4.13 (m, 2H), 3.43 (dd, J=7.2, 3.2 Hz, 1H), 3.29 (dd, J=15.6, 5.2 Hz, 1H), 2.99～2.80 (m, 1H), 2.70～2.63 (m, 1H), 1.27 (t, J=6.8 Hz, 3H); δ (minor isomer): 7.75～7.69 (m, 1H), 7.67～7.64 (m, 1H), 7.32～7.19 (m, 4H), 7.14～7.10 (m, 1H), 6.25 (d, J=1.6 Hz, 1H), 5.89～5.85 (m, 1H), 5.67 (d, J=1.2 Hz, 1H), 5.49～5.45 (m, 1H), 4.21～4.13 (m, 2H), 3.47 (dd, J=7.2, 3.2 Hz, 1H), 3.22 (dd, J=16.0, 6.0 Hz, 1H), 2.99～2.80 (m, 1H), 2.70～2.63 (m, 1H), 1.28 (t, J=6.8 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 190.48, 167.08, 144.60, 141.46, 141.45, 136.62, 133.99, 132.55, 128.10, 127.85, 127.76, 127.69, 121.61, 121.54, 81.70, 79.49, 60.70, 47.31, 39.48, 14.17; δ (minor isomer): 190.43, 167.08, 144.51, 141.45, 141.41, 136.60, 133.93, 132.43, 128.10, 127.81, 127.73, 127.54, 121.59, 121.47, 81.43, 79.12, 60.70, 46.53, 38.89, 14.17. HRMS (ESI) calcd for $C_{20}H_{20}NaO_4S$ $[M+Na]^+$ 379.0975, found 379.0977.

Ethyl-((3-(2-(4-chlorophenyl)-2-oxoethyl)-5-methoxy-1,3-dihydroisobenzofuran-1-yl)methyl)acrylate (**4m**): Colorless oil, 42.2 mg, 51% yield, *cis*∶*trans*=1∶1.1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.94～7.89 (m, 2H), 7.4～7.41 (m, 2H), 7.13～7.10 (m, 1H), 6.84～6.79 (m, 1H), 6.73～6.72 (m, 1H), 6.26 (d, J=0.8 Hz, 1H), 5.83～5.80 (m, 1H), 5.69 (s, 1H), 5.42～5.38 (m, 1H), 4.22～4.13 (m, 2H), 3.80 (s, 3H), 3.49～3.43 (m, 1H), 3.31～3.21 (m, 1H), 2.82 (dd, J=14.4, 4.0 Hz, 1H), 2.67～2.59 (m, 1H), 1.30～1.26 (m, 3H); δ (minor isomer): 7.94～7.89 (m, 2H), 7.4～7.41 (m, 2H), 7.13～7.10 (m, 1H), 6.84～6.79 (m, 1H), 6.73～6.72 (m, 1H), 6.22 (d, J=0.8 Hz, 1H), 5.74 (t, J=6.0 Hz, 1H), 5.60 (s, 1H), 5.35～5.32 (m, 1H), 4.22～4.13 (m, 2H), 3.81 (s, 3H), 3.49～3.43 (m, 1H), 3.31～3.21 (m, 1H), 2.95 (dd, J=14.4, 4.0 Hz, 1H), 2.67～2.59 (m, 1H), 1.30～1.26 (m, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 196.83, 167.08, 159.73, 143.22, 139.61, 136.61, 135.42, 133.53, 129.75, 128.84, 127.70, 122.42, 114.05, 106.72, 81.29, 78.79, 60.72, 55.50, 46.02, 38.90, 14.17; δ (minor isomer): 196.80, 167.08, 159.81, 143.14, 139.63, 136.67, 135.49, 133.55, 129.67, 128.86, 127.38, 122.25, 114.09, 106.69, 81.53, 79.15, 60.74, 55.52, 46.78, 39.40, 14.16. HRMS (ESI) calcd for $C_{23}H_{23}ClNaO_5$ $[M+Na]^+$ 437.1126, found 437.1140.

2-(3-(2-Bromoallyl)-1,3-dihydroisobenzofuran-1-yl)-1-phenylethan-1-one (**4n**): Yellow oil, 54.1 mg, 76% yield, *cis*∶*trans*=1∶1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.98 (t, J=7.2 Hz, 2H), 7.59～7.54 (m, 1H), 7.48～7.44 (m, 2H), 7.31～7.21 (m, 4H), 5.96～5.93 (m, 1H), 5.67 (s, 1H), 5.59～5.47 (m, 2H), 3.60～3.53 (m, 1H), 3.40～3.29 (m, 1H), 2.91～2.75 (m, 2H); δ (minor isomer): 7.98 (t, J=7.2 Hz, 2H), 7.59～7.54 (m, 1H), 7.48～7.44 (m, 2H), 7.31～7.21 (m, 4H), 5.85 (t, J=6.0 Hz, 1H), 5.62 (s, 1H), 5.59～5.47 (m, 2H), 3.60～3.53 (m, 1H), 3.40～3.29 (m, 1H), 2.91～2.75 (m, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.78, 141.72, 140.82, 136.98, 133.21, 129.33, 128.56, 128.21, 128.03, 127.81, 121.79, 121.56, 119.59, 80.28, 79.20, 48.25, 45.79; δ (major isomer): 197.69, 141.69, 140.76, 137.09, 133.21, 129.20, 128.56, 128.28, 128.03, 127.75, 121.65, 121.47, 119.45, 80.50, 79.58, 49.09, 46.51. HRMS (ESI) calcd for $C_{19}H_{17}BrNaO_2$ $[M+Na]^+$ 379.0304, found 379.0289.

1-Phenyl-2-(3-(1-phenylallyl)-1,3-dihydroisobenzofuran-1-yl)ethan-1-one (**4o**): Colorless oil, 36.1 mg, 51% yield, *cis*∶*trans*=1∶1.1. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 7.96～7.91 (m, 2H), 7.57～7.52 (m, 1H), 7.46～7.41 (m, 2H), 7.29～7.11 (m, 8H), 6.69 (d, J=7.6 Hz, 1H), 6.20～6.10 (m, 1H), 5.83～5.76 (m, 1H), 5.56～5.53 (m, 1H), 5.12～5.05 (m, 1H), 4.99～4.93 (m, 1H), 3.61 (t, J=6.8 Hz, 1H), 3.56～3.03 (m, 2H); δ (minor isomer): 7.96～7.91 (m, 2H), 7.57～7.52 (m, 1H), 7.46～7.41 (m, 2H), 7.29～7.11 (m, 8H), 6.82 (d, J=8.0 Hz, 1H), 6.20～6.10 (m, 1H), 5.83～5.76 (m, 1H), 5.56～5.53 (m, 1H), 5.12～5.05 (m, 1H), 4.99～4.93 (m, 1H), 3.71 (t, J=6.8 Hz, 1H), 3.56～3.03 (m, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.92, 142.34, 140.73, 140.51, 137.65, 137.11, 133.14, 128.91, 128.54, 128.34, 128.24, 127.79, 127.32, 126.71, 122.09, 121.49, 117.02, 86.03, 79.55, 56.24, 46.02; δ (minor isomer): 198.01, 142.24, 140.49, 140.14, 137.88, 137.10, 133.14, 129.25, 128.49, 128.32, 128.30, 127.87, 127.46, 126.76, 122.21, 121.47, 117.06, 86.48, 79.55, 56.20, 46.26. HRMS (ESI) calcd for $C_{25}H_{22}NaO_2$ $[M+Na]^+$ 377.15120, found 377.15118.

2-(3-(2-Methylbut-3-en-2-yl)-1,3-dihydroisobenzofuran-1-yl)-1-phenylethan-1-one (**4p**): Colorless oil, 37.4 mg, 61%). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.97～7.95 (m, 2H), 7.54 (t, J=7.6 Hz, 1H), 7.44 (t, J=8.0 Hz, 2H), 7.27～7.18 (m, 4H), 5.95～5.87 (m, 2H), 5.06～4.97 (m, 3H), 3.54～3.49 (dd, J=18.4, 6.0 Hz, 1H), 3.28～3.22 (dd, J=16.4, 6.0 Hz, 1H), 1.11 (s, 3H), 0.97 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ: 198.06, 144.68, 142.91, 139.66, 137.17, 133.12, 128.53, 128.24, 127.68, 127.03, 123.03, 121.44, 112.98, 90.09, 79.71, 46.50, 43.09, 24.34, 21.15; HRMS (ESI) calcd for $C_{21}H_{22}NaO_2$ $[M+Na]^+$ 329.15120, found 329.15123.

2-(3-(Cyclohex-2-en-1-yl)-1,3-dihydroisobenzofuran-1-yl)-1-phenylethan-1-one (**4q**): Colorless oil, 27.4 mg, 43%

yield, *cis*∶*trans*=1∶2.6. ^{1}H NMR (400 MHz, $CDCl_3$) δ (major isomer): 8.01～7.94 (m, 2H), 7.57～7.52 (m, 1H), 7.47～7.42 (m, 2H), 7.28～7.18 (m, 4H), 5.92～5.68 (m, 3H), 5.27 (t, J=3.6 Hz, 1H), 3.63～3.54 (m, 1H), 3.34～3.27 (m, 1H), 2.59～2.53 (m, 1H), 2.00 (s, 2H), 1.79～1.68 (m, 1H), 1.58～1.41 (m, 3H); δ (minor isomer): 8.01～7.94 (m, 2H), 7.57～7.52 (m, 1H), 7.47～7.42 (m, 2H), 7.28～7.18 (m, 4H), 5.92～5.68 (m, 3H), 5.21～5.20 (m, 1H), 3.63～3.54 (m, 1H), 3.34～3.27 (m, 1H), 2.59～2.53 (m, 1H), 2.00 (s, 2H), 1.79～1.68 (m, 1H), 1.58～1.41 (m, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ (major isomer): 197.95, 142.42, 140.61, 137.09, 133.15, 129.62, 128.55, 128.46, 128.21, 127.62, 127.57, 121.83, 121.58, 86.05, 79.68, 46.18, 41.65, 25.15, 23.15, 21.33; δ (minor isomer): 198.10, 142.46, 140.70, 137.18, 133.18, 129.38, 128.55, 128.39, 128.36, 127.63, 127.61, 121.65, 121.63, 86.02, 79.23, 46.32, 40.97, 25.20, 23.55, 21.35. HRMS (ESI) calcd for $C_{22}H_{22}NaO_2$ $[M+Na]^+$ 341.15120, found 341.15129.

Supporting Information Copies of ^{1}H NMR, ^{13}C NMR, ^{19}F NMR spectra and the HRMS data of compounds **3** and **4**. The Supporting Information is available free of charge via the Internet at http://sioc-journal.cn/.

References

[1] Karmakar, R.; Pahari, P.; Mal, D. *Chem. Rev.* **2014**, *114*, 6213.
[2] Lovey, R. G.; Elliott, A. J.; Kaminski, J. J.; Loebenberg, D.; Parmegiani, R. M.; Rane, D. F.; Girijavallabhan, V. M.; Pike, R. E.; Guzik, H.; Antonacci, B. *J. Med. Chem.* **1992**, *35*, 4221.
[3] Len, C.; Selouane, A.; Postel, D.; Villa, P.; Aubertin, A.-M.; Egron, D.; Gosselin, G.; Périgaud, C. *Nucleos. Nucleot. Nucl.* **2003**, *22*, 943.
[4] Coote, S. J.; Davies, S. G.; Middlemiss, D.; Naylor, A. *J. Organomet. Chem.* **1989**, *379*, 81.
[5] Luzzio, F. A.; Okoromoba, O. E. *Tetrahedron Lett.* **2011**, *52*, 6530.
[6] Yuan, H.; Gong, Y. *J. Fluorine Chem.* **2013**, *149*, 125.
[7] Wei, X.; Chen, G.; Peng, Y. *Tetrahedron Lett.* **2020**, *61*, 152174.
[8] Maity, S.; Saha, M.; Hazra, G.; Ghorai, P. *Org. Lett.* **2017**, *19*, 5872.
[9] Nath, U.; Chowdhury, D.; Pan, S. C. *Adv. Synth. Catal.* **2018**, *360*, 1628.
[10] Yang, X.; Pang, S.; Cheng, F.; Zhang, Y.; Lin, Y.-W.; Yuan, Q.; Zhang, F.-L.; Huang, Y.-Y. *J. Org. Chem.* **2017**, *82*, 10388.
[11] Bao, M.; Nakamura, H.; Inoue, A.; Yamamoto, Y. *Chem. Lett.* **2002**, *31*, 158.
[12] Capriati, V.; Florio, S.; Luisi, R.; Perna, F. M.; Salomone, A. *J. Org. Chem.* **2006**, *71*, 3984.
[13] Chao, B.; Dittmer, D. C. *Tetrahedron Lett.* **2000**, *41*, 6001.
[14] Jarrige, L.; Carboni, A.; Dagousset, G.; Levitre, G.; Magnier, E.; Masson, G. *Org. Lett.* **2016**, *18*, 2906.
[15] Mukaiyama, T.; Harada, T. *Chem. Lett.* **1981**, *10*, 1527.
[16] (a) Zhao, P.; Huang, D.; Wang, F.; Han, T.; Yang, M.; Wang, K. H.; Hu, Y. *Appl. Organomet. Chem.* **2021**, *36*, e6479.
(b) Wang, S.; Wang, K. H.; Chang, B.; Huang, D.; Hu, Y. *Appl. Organomet. Chem.* **2021**, *35*, e6249.
(c) Wang, X.; Huang, D.; Wang, K. H.; Liu, J.; Zong, W.; Wang, J.; Su, Y.; Hu, Y. *Appl. Organomet. Chem.* **2019**, *33*, e4995.
(d) Wang, X.; Huang, D.; Wang, K. H.; Su, Y.; Hu, Y. *J. Org. Chem.* **2019**, *84*, 6946.
(e) Elaas, N. A.; Elaas, W. A.; Huang, D.; Hu, Y.; Wang, K.-H. *Curr. Org. Synth.* **2017**, *14*, 1156.
[17] Zhao, Z.; Wang, J.; Huang, D.; Yang, Z.; Zhao, F.; Hu, Y.; Xu, W.; Hu, Y. *Chin. J. Org.Chem.* **2020**, *40*, 2026 (in Chinese).
(赵转霞, 王君姣, 黄丹凤, 杨政, 赵芳霞, 虎永琴, 徐炜刚, 胡雨来, 有机化学, **2020**, *40*, 2026.)
[18] (a) Yamamoto, Y.; Asao, N. *Chem. Rev.* **1993**, *93*, 2207.
(b) Zha, Z.; Qiao, S.; Jiang, J.; Wang, Y.; Miao, Q.; Wang, Z. *Tetrahedron* **2005**, *61*, 2521.
[19] Marshall, J. A. *Chem. Rev.* **1996**, *96*, 31.
[20] Roy, U. K.; Roy. S. *Chem. Rev.* **2010**, *110*, 2472.
[21] Shen, Z.-L.; Wang, S.-Y.; Chok, Y.-K.; Xu, Y.-H.; Loh, T.-P. *Chem. Rev.* **2013**, *113*, 271.
[22] Tan, K.-T.; Chng, S.-S.; Cheng, H.-S.; Loh, T.-P. *J. Am. Chem. Soc.* **2003**, *125*, 2958.
[23] Zhang, J.; Blazecka, P. G.; Berven, H.; Belmont, D. *Tetrahedron Lett.* **2003**, *44*, 5579.
[24] Wang, Z.; Zha, Z.; Zhou, C. *Org. Lett.* **2002**, *4*, 1683.
[25] Zha, Z.; Xie, Z.; Zhou, C.; Chang, M.; Wang, Z. *New J. Chem.* **2003**, *27*, 1297.
[26] (a) Ravindra, B.; Das, B. G.; Ghorai, P. *Org. Lett.* **2014**, *16*, 5580.
(b) Kumar, P.; Shirke, R. P.; Yadav, S.; Ramasastry, S. S. V. *Org. Lett.* **2021**, *23*, 4909.
[27] Tripathi, C. B.; Mukherjee, S. *Angew. Chem., Int. Ed.* **2013**, *52*, 8450.

(Cheng, F.)

