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Regioselective Synthesis of Isochromenones by Iron(III)/PhSeSePh-Mediated Cyclization of 2-Alkynylaryl Esters

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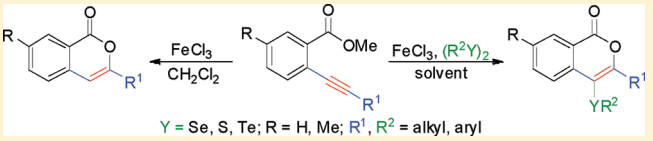
Supporting Information

ABSTRACT: A series of 4-Se-(Te, S)-isochromenones and 3-substituted isochromenones were synthesized in good yields via $FeCl_3$-mediated cyclization of alkynylaryl esters with different diorganyl dichalcogenides. This methodology was carried out at room temperature, using inexpensive and environmentally friendly iron salts as metallic source and under air atmosphere. The reaction showed to be tolerant to a range of substituents bonded into the aromatic ring of the diorganyl dichalcogenides as well as to alkyl groups directly bonded to the chalcogen atom. Alternatively, the cyclization reaction of 2-alkynylaryl esters with $FeCl_3$, in the absence of diorganyl dichalcogenide, gave the isochromenones without the chalcogen moiety in the structure. This approach proved to be highly regioselective, providing only six-membered ring products, once the possible five-membered products were not observed in any experiments.

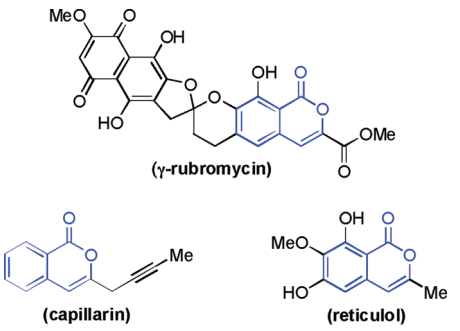


INTRODUCTION

Compounds containing an oxygenated heterocyclic ring and their derivatives are of growing importance as targets for synthesis, largely because of their presence in numerous compounds of biological interest and importance as medical and biochemical agents. Among them, six-membered lactone derivatives and, in particular, chromenones represent an important class of naturally occurring compounds that display a range of biological activities.[1] In fact, a large number of chromenones have been isolated from a variety of plant sources and have been largely studied in respect to their potential therapeutic applications.[2] Some chromenone derivatives have proven to be antimicrobial,[3] anticancer,[4] antioxidant and anti-inflammatory,[5] anti-HIV,[6] and anticoagulant[7] agents. Typical examples include reticulol (Scheme 1), described as a potent inhibitor of cyclic nucleotide phosphodiesterase, a topoisomerase I inactivator and an inhibitor of lung metastasis.[8] In addition, capillarin (Scheme 1), which contains a propargyl group at the 3-position of the heterocyclic ring, shows a potent antifungal activity.[9] Moreover, γ-rubromycin (Scheme 1) has been synthesized as a potential drug for the inhibition of HIV reverse transcriptase and human telomerase.[10]

These findings have stimulated a great interest not only in synthetic studies but also a potentially wide variety of industrial applications.[11] Different methods for the synthesis of chromenones were reported in the literature, including classical approaches such as transition-metal-catalyzed reactions[12] and intramolecular electrophilic cyclization protocols.[13] These methods have been recognized as powerful protocols for both carbon and heterocycle formation. However, in the past 10 years significant efforts have been made to develop ideal

Scheme 1



Scheme 1

environmentally friendly atom-economical protocols to prepare heterocycles. Among such protocols, the use of iron salts has attracted much attention from the advantage of synthetic chemistry due to its facile execution and generally high yields of products.[14] Iron species proved to be effective to provide coupling reactions between Grignard species and various organic electrophiles,[15] as well as C−N[16] and C-chalcogen[17] bond formation. In the heterocycle synthesis, $FeCl_3$-mediated intramolecular cyclization was reported as an excellent choice to prepare benzofuran derivatives via direct oxidative aromatic C−O bond formation, using electron-rich aryl ketones as starting materials.[18] Recently, iron(III) salts are also shown to be excellent catalysts for the new aza-Cope−Mannich cyclization

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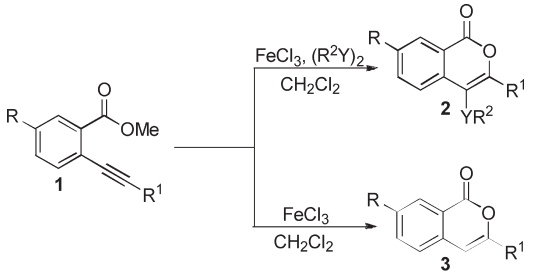
Scheme 2

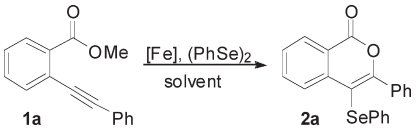


using homopropargyl tosylamine in the preparation of pyrrolidines.[19] Bolm and co-workers have demonstrated that $FeCl_3$ and 2,2,6,6-tetramethyl-3,5-heptanedione (TMHD) are effective as a catalytic system for an iron-catalyzed intramolecular O-arylation reaction of 2-haloanilines in the synthesis of benzoxazole derivatives.[20] The effectiveness of the iron salts as Lewis acids was evaluated in the synthesis of piperidine derivatives starting from *N*-tosylimines.[21] Recently, others[22] and we[23] have shown that $FeCl_3$/diorganyl dichalcogenides is an alternative system to the classical protocols to promote cyclization of unsaturated substrates. Besides, the incorporation of an organoselenium or organotellurium group in the structure of molecules has attracted much attention due to their applications in several different reactions,[24] such as selenoxide *syn* elimination, [2,3]-sigmatropic rearrangement, cyclization, and cross-coupling reactions, as well as their biological properties.[25] In connection with our current research interests in this area and in order to widen the scope and generality of the application of Fe(III)/RSeSeR in the cyclization methodologies, the fact that currently there are no reports concerning the use of $FeCl_3$ to prepare isochromenone derivatives encouraged us to examine if 4-organoselenyl isochromenones **2** and isochromenones **3** would be generated from alkynylaryl esters **1**[26] via intramolecular cyclization reactions using $FeCl_3$/RYYR as the cyclizing agent (Scheme 2).

RESULTS AND DISCUSSION

Initial $FeCl_3$-mediated cyclization attempts were focused on finding a general set of reaction conditions that could be used with a variety of alkynylaryl esters and diorganyl dichalcogenides for the preparation of 4-chalcogen-isochromenones **2**. For this purpose, the mixture of **1a** (0.25 mmol) with $FeCl_3$ (1.5 equiv) and diphenyl diselenide (1.5 equiv) in CH_2Cl_2 (5 mL), at reflux under argon atmosphere was employed in the cyclization of the alkynylaryl ester **1**. Using this condition, **2a** was obtained with 63% yield (Table 1, entry 1). In order to improve the yield further, other parameters such as solvent, diphenyl diselenide loading, iron trichloride loading, and temperature were screened. It was gratifying to discover that diphenyl diselenide loading could be reduced from 1.5 to 0.5 equiv, with an increase in the yield (Table 1, entry 2). This result suggests that the two portions of diphenyl diselenide (PhSe) were incorporated in the final product and indicates atom economy, which is an important concept of green chemistry philosophy. Most importantly, the experimental conditions described in Table 1, entry 4 demonstrated that the reactions could be carried out at room temperature and under air atmosphere, respectively, giving the cyclized

Table 1. Influence of Reaction Conditions for the Formation of 2a



entry	[Fe] (equiv)	$(PhSe)_2$ (equiv)	solvent	yield (%)[a]
1	$FeCl_3$ (1.5)	1.5	CH_2Cl_2	63[b]
2	$FeCl_3$ (1.5)	0.5	CH_2Cl_2	89[b]
3	$FeCl_3$ (1.5)	0.5	CH_2Cl_2	98[c]
4	$FeCl_3$ (1.5)	0.5	CH_2Cl_2	99
5	$FeCl_3$ (1.0)	0.5	CH_2Cl_2	73
6	$FeCl_3$ (1.5)	0.5	DMF	0
7	$FeCl_3$ (1.5)	0.5	dioxane	0
8	$FeCl_3$ (1.5)	0.5	CH_3CN	52
9	$FeCl_3$ (0.2)	0.5	CH_2Cl_2	28
10	$FeCl_3$ (0.2)	1.0	CH_2Cl_2	28
11	$Fe(acac)_3$ (1.5)	0.5	CH_2Cl_2	0
12	$FeCl_2 \cdot 4H_2O$ (1.5)	0.5	CH_2Cl_2	26
13	$FeCl_3 \cdot 6H_2O$ (1.5)	0.5	CH_2Cl_2	52
14	Fe^0 (1.5)	0.5	CH_2Cl_2	0
15	$FeCl_3$ (1.5)		CH_2Cl_2	77[d]

[a] Reactions performed under air, at room temperature for 18 h. Yields were determined by GC analysis. [b] Reaction performed under reflux in argon atmosphere. [c] Reaction performed under argon atmosphere, at room temperature. [d] The product obtained was 3-phenyl-isochromenone without the PhSe group at the 4-position.

product **2a** in high yield. After that, the alterations in other parameters, such as reducing the iron trichloride loading from 1.5 to 0.2 equiv and changing the iron sources and solvents proved to be inefficient (Table 1, entries 6−14). However, when the reaction was carried out using 1.5 equiv of $FeCl_3$ in the absence of diphenyl diselenide, we obtained the 3-phenyl-isochromenone, without the PhSe group at the 4-position, in 77% yield. To our knowledge the preparation of isochromenones in such way has not been reported to date.

Once the best conditions were established, we next explored the effect of different functional groups on the aromatic ring directly bonded to alkyne. The reaction showed to be sensitive to electronic effects of these aryl substituents (Table 2, **2a**−**h**). Electron-withdrawing groups provided the corresponding isochromenones in good yields (Table 2, **2b,c**). However, the strong electron-donating MeO and Me_2N groups promoted a significant decrease in the yield of the reactions, probably due to a decrease in the electrophilicity of the triple bond (Table 2, **2d,e**). On the other hand, this cyclization reaction was not sensitive to the electronic effects of substituents in the aromatic ring of diaryl diselenides. Our results showed that the cyclized products were obtained in good yields for diaryl diselenides having electron-rich, -neutral, and -poor groups at the aromatic ring (Table 2, **2h**−**k**). In addition to diaryl diselenides, dialkyl diselenides were also effective to give 4-selenosubstituted isochromenones (Table 2, **2l**−**n**).

In the context of organochalcogens, organotellurium and organosulfur derivatives and, in particular, vinyl tellurides and vinyl sulfides play an important role as key intermediates in a number of synthetic approaches to the preparation of

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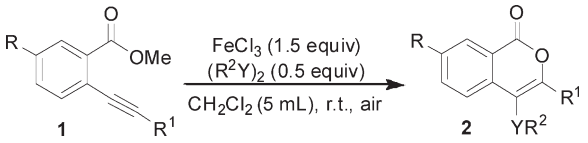
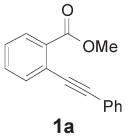
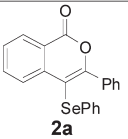
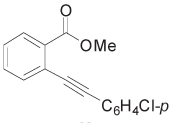
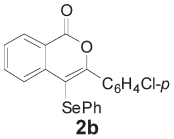
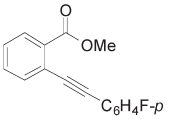
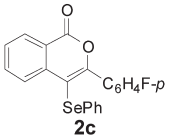
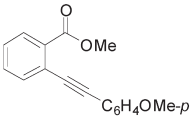
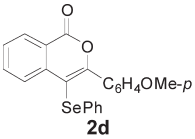
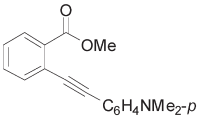
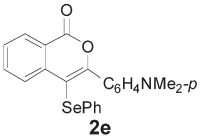
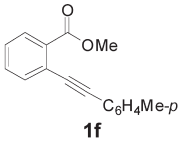
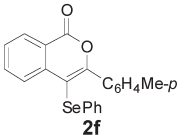
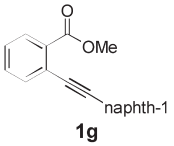
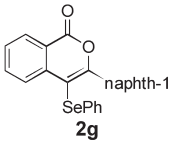
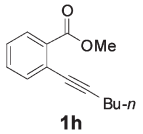
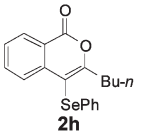
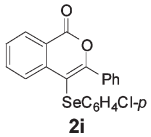
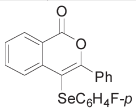
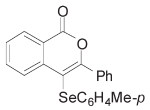
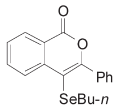
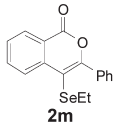
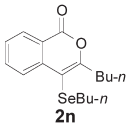
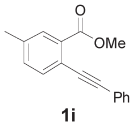
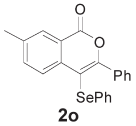
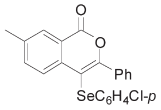
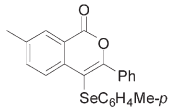
molecules that have interesting biological properties as well as in the chemistry of materials.[27,28] Our research group has applied these compounds in the synthesis of natural products[29] and antidepressant molecules.[30] Considering these aspects and in order to expand the scope of our methodology, we tested the same reaction conditions described in Table 2 with alkynylaryl ester **1a** using dimethyl disulfide and dibutyl and diphenyl ditellurides as the organochalcogen source, providing the cyclized products **2r**, **2s**, and **2t** in 65%, 75%, and 35% yields, respectively (Scheme 3). With regard to five- versus six-membered rings, it is important to point out that the unique product obtained during the course of this cyclization was the six-membered ring, which was determined by X-ray diffraction analysis (Figure 1, Supporting Information).

Table 2. Cyclization Reactions of 2-Alkynylaryl Esters Mediated by $FeCl_3$/Diorganyl Diselenides[a]



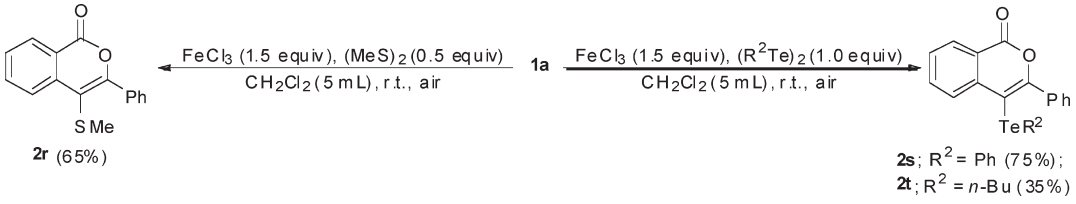
entry	alkynylaryl esters	$(R^2Y)_2$	product	yield (%)
1	 **1a**	$(PhSe)_2$	 **2a**	87
2	 **1b**	$(PhSe)_2$	 **2b**	80
3	 **1c**	$(PhSe)_2$	 **2c**	64
4	 **1d**	$(PhSe)_2$	 **2d**	45
5	 **1e**	$(PhSe)_2$	 **2e**	35
6	 **1f**	$(PhSe)_2$	 **2f**	71
7	 **1g**	$(PhSe)_2$	 **2g**	77
8	 **1h**	$(PhSe)_2$	 **2h**	74
9	**1a**	$(p\text{-}ClC_6H_4Se)_2$	 **2i**	80

dx.doi.org/10.1021/jo201211s |J. Org. Chem. 2011, 76, 6789–6797

entry	alkynylaryl esters	$(R^2Y)_2$	product	
10	1a	$(p\text{-}FC_6H_4Se)_2$	 2j	73
11	1a	$(p\text{-}MeC_6H_4Se)_2$	 2k	68
12	1a	$(n\text{-}BuSe)_2$	 2l	76
13	1a	$(EtSe)_2$	 2m	85
14	1h	$(n\text{-}BuSe)_2$	 2n	67
15	 1i	$(PhSe)_2$	 2o	75
16	1i	$(p\text{-}ClC_6H_4Se)_2$	 2p	72
17	1i	$(p\text{-}MeC_6H_4Se)_2$	 2q	74

[a] Reactions were performed by using **1** (0.25 mmol), CH_2Cl_2 (5 mL), at room temperature under air atmosphere for 18 h.

Scheme 3



Considering that little is known about the reaction of diorganyl diselenides with $FeCl_3$,[31] a proposal mechanism for the $FeCl_3/R^2YYR^2$-mediated cyclization could be a matter of speculation. However, we are working to clarify this mechanism, and the following experimental data have been obtained in these studies: (1) When $FeCl_3$ and diphenyl diselenide reacted, under identical reaction conditions used to obtain the cyclized products, in the absence of the starting alkynylaryl ester **1a**, no PhSeCl was detected when the crude reaction mixture was analyzed by GC−MS. This indicates that the pathway does not follow the typical electrophilic cyclization, in which the electrophilic source is PhSeCl[32] (Scheme 4a). (2) When the order of the reagent addition was changed and diphenyl diselenide was added last, only the isochromenone, without PhSe in the structure, was obtained. This suggests that the cyclization mediated by $FeCl_3$ followed by the replacement of C−Fe bond by diphenyl diselenide, which would act as an electrophile source, does not occur (Scheme 4b). (3) When the reaction was carried out using the alkynylaryl ester **1j** as

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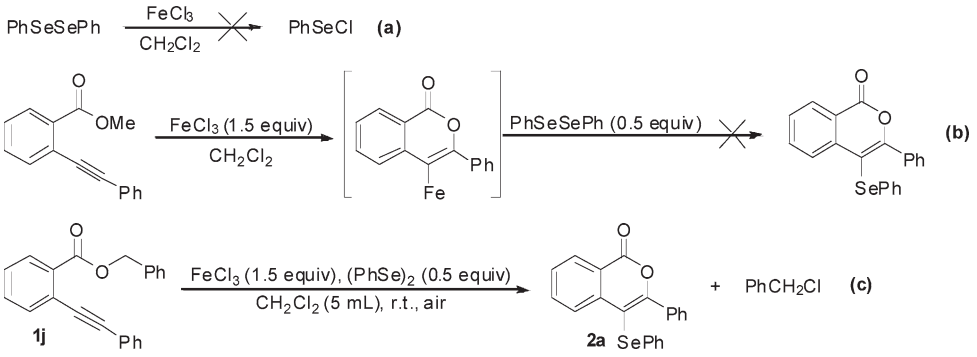
Scheme 4



substrate, which has a benzyloxy group directly bonded to carbonyl function, we obtained a mixture of desired isochromenone **2a** and benzyl chloride (Scheme 4c). This implies that the chloride ion is acting as a nucleophile in the benzyl cleavage, via an S_N2 removal.[33] Further mechanistic investigations to elucidate a mechanism for the reaction are underway.

Over the past years isochromenones have been most commonly synthesized via copper catalysis[34] and via Bronsted acid[35] promoted cyclizations of alkynylaryl esters. The superiority of this method was proved by the mild conditions, high yields of the desired products, and the tolerance for various substituents. Inspired by these findings and considering that the cyclization of 2-alkynylaryl ester **1a** to isochromenone occurred in good yield using only $FeCl_3$ and CH_2Cl_2 (Table 1, entry 15) and that no evidence for direct cyclization of alkynyl ester promoted by Fe(III) salts was obtained, we decided to investigate whether the reaction system reported in this study is applicable to the intramolecular cyclization of other 2-alkynylaryl esters. After some screening, it was found that the $FeCl_3$ amount, solvent, and temperature were important parameters to obtain the cyclized products in high yields. For example, when the amount of $FeCl_3$ was studied, by varying from catalytic ratio to 1.5 equiv, the results showed that 1.0 equiv proved to be most effective. Moreover, the change of CH_2Cl_2 to other polar and apolar aprotic solvents did not improve the reaction results and in contrast lowered the reaction yields. This indicates that, considering the solvents tested, the reaction can proceed effectively only in CH_2Cl_2. Additionally, all optimized reaction conditions were also carried out at reflux and under argon atmosphere, which proved to be inefficient to increase the yields. These results are attractive from an economic point of view. Therefore, it may be concluded that the mixture of alkynylaryl esters **1** (0.25 mmol) and $FeCl_3$ (1.0 equiv) in CH_2Cl_2 (5 mL), at room temperature in an open tube (under air atmosphere) could be used as the standard condition.

The standard condition, which was obtained as a result of the optimization reactions, was subsequently tested on a variety of alkynylaryl esters, and these results are presented in Table 3. Satisfactorily, most of the reactions proceeded smoothly to afford the corresponding isochromenones in good to excellent yields. Our synthetic method was shown to tolerate alkynylaryl esters substituted with electron-neutral, electron-rich, and electron-poor groups in the aromatic ring directly bonded to alkyne (Table 3, entries 1−6), although electron-poor groups led to slightly diminished yields (Table 3, entries 5 and 6). The bulky naphthyl group in alkyne did not greatly influence the yield, giving the cyclized product equally in good yield (Table 3, entry 7). By contrast, lower yield was observed for alkynylaryl ester with an alkyl group directly bonded to the triple bond (Table 3, entry 8). The cyclization with alkynylaryl esters, containing a substituent in the aromatic ring, smoothly gave the expected cyclized products in good yields (Table 3, entries 9−11). However, the yield remained modest to **3l** (54%) due to the instability of this product during its purification (Table 3, entry 12).

CONCLUSION

In summary, we studied the cyclization reaction behavior of 2-alkynylaryl esters promoted by $FeCl_3$ and diorganyl dichalcogenides, showing that the six-membered ring was selectively obtained in good yields when the reaction was carried out at room temperature under air atmosphere. This procedure was successfully applied in the cyclization of 2-alkynylaryl esters with diorganyl dichalcogenides bearing various functionalities. The reactions tolerated not only diorganyl diselenides but also diorganyl ditellurides and disulfides, generally resulting in reasonable to good yields, and proceeded under relatively mild conditions. In addition, when the reaction was carried out using only $FeCl_3$ without diphenyl diselenide, we obtained isochromenones as the product, without the RY group at the 4-position. This result is significant since using the same reaction conditions we obtained two classes of isochromenones. Furthermore, since iron salts are easily available commercially, less expensive, and relative nontoxic, our method could be considered an economic and eco-friendly protocol.

EXPERIMENTAL SECTION

General Procedure for 4-Chalcogen-isochromen-1-ones. In a Schlenk tube, under air, containing dichloromethane (4 mL) were added $FeCl_3$ (0.061 g, 1.5 equiv, 99.99% purity from commercial suppliers) and diorganyl dichalcogenides (0.5 equiv), and the reaction was stirred for 20 min at room temperature. After this time was added 2-alkynylaryl esters (0.25 mmol) in dichloromethane (1 mL), and the reaction mixture was stirred for 18 h at the same temperature. After this, the mixture was diluted with dichlorometane (20 mL) and washed with a saturated solution of NH_4Cl (20 mL). The organic phase was separated, dried over $MgSO_4$, and concentrated under vacuum. The residue was purified by flash chromatography and eluted with hexane/acetate (95:5).

3-Phenyl-4-(phenylselenyl)-1*H*-isochromen-1-one (2a). Yield: 0.082 g (87%). ^1H NMR ($CDCl_3$, 200 MHz): δ 8.36 (dd, J =

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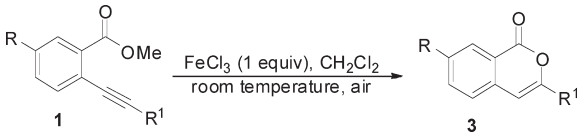
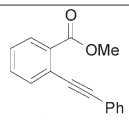
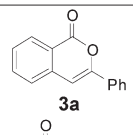
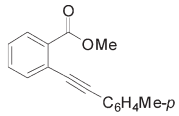
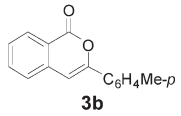
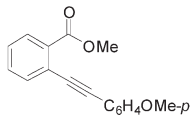
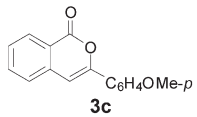
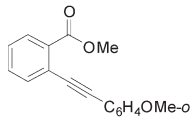
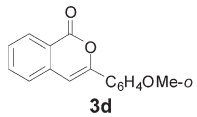
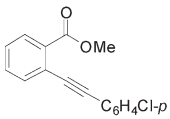
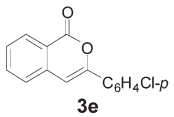
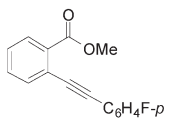
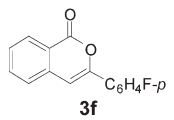
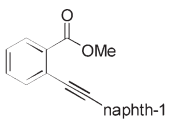
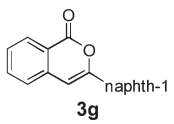
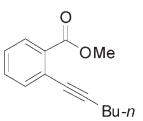
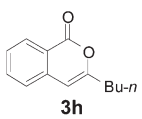
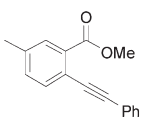
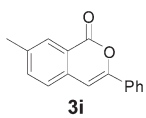
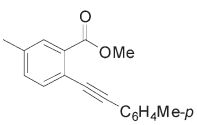
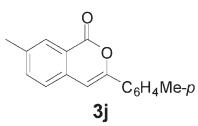
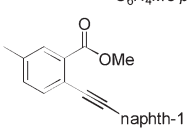
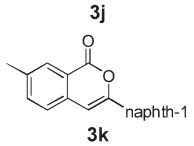
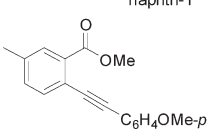
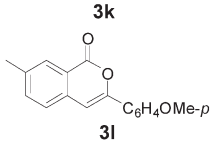
Table 3. Cyclization Reactions of 2-Alkynylaryl Esters Mediated by $FeCl_3$[a]



entry	alkynylaryl ester	product	yield (%)
1		 **3a**	84
2		 **3b**	79
3		 **3c**	80
4		 **3d**	84
5		 **3e**	63
6		 **3f**	60
7		 **3g**	68
8		 **3h**	48
9		 **3i**	65
10		 **3j**	81
11		 **3k**	83
12		 **3l**	54

[a] Reaction performed in the presence of **1** (0.25 mmol), $FeCl_3$ (1.0 equiv), CH_2Cl_2 (5 mL), at room temperature under air atmosphere for 12 h.

7.8 Hz, J = 1.0 Hz, 1H), 8.06−8.02 (m, 1H), 7.74−7.62 (m, 3H), 7.57−7.48 (m, 1H), 7.45−7.34 (m, 3H), 7.24−7.14 (m, 5H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.7, 159.6, 138.4, 135.3, 133.9, 131.8, 130.0, 129.7, 129.6, 129.4, 128.8, 128.7, 128.2, 127.8, 126.4, 120.8, 104.7. MS (relative intensity) m/z: 378 ([M + 1] 24), 270 (11), 207 (13), 193 (17), 165 (31), 105 (100), 77 (19). Anal. Calcd for $C_{21}H_{14}O_2Se$: C 66.85, H 3.74. Found: C 66.92, H 3.82.

3-(4-Chlorophenyl-4-phenylselenyl)-1*H*-isochromen-1-one (2b). Yield: 0.082 g (80%). ^1H NMR ($CDCl_3$, 200 MHz): δ 8.34 (dd, J = 7.8 Hz, J = 1.0 Hz, 1H), 8.06−8.02 (m, 1H), 7.74−7.66 (m, 1H), 7.64−7.49 (m, 3H), 7.38−7.32 (m, 2H), 7.17−7.13 (m, 5H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.3, 158.2, 141.2, 138.2, 135.4, 132.3, 131.5, 130.9, 129.7, 129.5, 128.8, 128.7, 128.2, 128.0, 126.5, 120.5, 105.9. MS (relative intensity) m/z: 412 ([M + 1] 30), 304 (20), 273 (13), 193 (11), 139 (100), 111 (13). Anal. Calcd for $C_{21}H_{13}ClO_2Se$: C 61.26, H 3.18. Found: C 61.26, H 3.22.

3-(4-Fluorophenyl-4-phenylselenyl)-1*H*-isochromen-1-one (2c). Yield: 0.063 g (64%). ^1H NMR ($CDCl_3$, 400 MHz): δ 8.35 (dd, J = 7.6 Hz, J = 1.0 Hz, 1H), 8.10−8.00 (m, 1H), 7.75−7.62 (m, 3H), 7.57−7.49 (m,1H), 7.18−7.03 (m, 7H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 163.6 (d, $^1J_{CF}$ = 251.0 Hz), 161.4, 158.5, 138.4, 135.4, 131.8 (d, $^3J_{CF}$ = 8.7 Hz), 131.6, 130.1 (d, $^4J_{CF}$ = 3.6 Hz), 129.7, 129.5, 128.8, 128.7, 128.2, 126.5, 120.8, 114.9 (d, $^2J_{CF}$ = 21.9 Hz), 104.9. MS (relative intensity) m/z: 396 ([M + 1] 28), 288 (23), 211 (10), 183 (18), 165 (16), 123 (100), 95 (14). Anal. Calcd for $C_{21}H_{13}FO_2Se$: C 63.81, H 3.31. Found: C 63.98, H 3.39.

3-(4-Methoxyphenyl-4-phenylselenyl)-1*H*-isochromen-1-one (2d). Yield: 0.046 g (45%). ^1H NMR ($CDCl_3$, 200 MHz): δ 8.34 (dd, J = 7.8 Hz, J = 1.0 Hz, 1H), 8.04−8.00 (m, 1H), 7.73−7.61 (m, 3H), 7.55−7.47 (m, 1H), 7.22−7.14 (m, 5H), 6.94−6.87 (m, 2H), 3.84 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.0, 159.5, 138.7, 135.3, 132.0, 131.3, 129.6, 129.4, 128.6, 128.4, 128.1, 126.4, 126.3, 120.6, 113.1, 103.7, 55.3. MS (relative intensity) m/z: 408 (M + 1] 32), 300 (89), 223 (17), 152 (16), 135 (100), 107 (10), 77 (15). Anal. Calcd for $C_{22}H_{16}O_3Se$: C 64.87, H 3.96. Found: C 64.95, H 3.91.

3-(4-(Dimethylamino)phenyl-4-phenylselenyl)-1*H*-isochromen-1-one (2e). Yield: 0.037 g (35%). ^1H NMR ($CDCl_3$, 400 MHz): δ 8.32−8.30 (m, 1H), 7.99−7.97 (m, 1H), 7.65−7.61 (m, 3H), 7.46−7.42 (m, 1H), 7.24−7.11 (m, 5H), 6.66−6.64 (m, 2H), 2.99 (s, 6H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.1, 160.3, 151.4, 139.3, 135.1, 132.4, 131.1, 129.5, 129.4, 128.5, 127.9, 127.7, 126.1, 121.0, 120.5, 110.6, 101.9, 40.0. MS (relative intensity) m/z: 421 ([M + 1] 54), 341 (51), 313 (85), 281 (36), 236 (67), 207 (70), 148 (100), 73 (43). Anal. Calcd for $C_{23}H_{19}NO_2Se$: C 65.72, H 4.56, N 3.33. Found: C 65.89, H 4.61, N 3.38.

4-(Phenylselenyl)-3-*p*-tolyl-1*H*-isochromen-1-one (2f). Yield: 0.069 g (71%). ^1H NMR ($CDCl_3$, 200 MHz): δ 8.34 (dd, J = 7.8 Hz, J = 1.0 Hz, 1H), 8.05−7.99 (m, 1H), 7.79−7.64 (m, 1H), 7.59−7.46 (m, 3H), 7.28−7.14 (m, 7H), 2.39 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.7, 159.7, 140.4, 138.5, 135.2, 131.9, 131.1, 129.6, 129.5, 129.4, 128.7, 128.5, 128.4, 128.1, 126.3, 120.7, 104.2, 21.4. MS (relative intensity) m/z: 392 ([M + 1] 25), 284 (32), 207 (9), 165 (10), 119 (100), 91 (20). Anal. Calcd for $C_{22}H_{16}O_2Se$: C 67.52, H 4.12. Found: C 67.68, H 4.19.

3-(Naphthalen-1-yl)-4-(phenylselenyl)-1*H*-isochromen-1-one (2g). Yield: 0.082 g (77%). ^1H NMR ($CDCl_3$, 200 MHz): δ 8.41 (dd, J = 7.8 Hz, J = 1.0 Hz, 1H), 8.08−8.03 (m, 1H), 7.95−7.85 (m, 2H), 7.77−7.69 (m, 2H), 7.60−7.39 (m, 6H), 7.14−7.06 (m, 4H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.7, 158.8, 138.0, 135.4, 134.8, 133.2, 131.8, 131.3, 130.3, 129.8, 129.6, 129.2, 128.9, 128.4, 128.0, 126.9, 126.5, 126.2, 124.8, 124.6, 121.1, 108.1. MS (relative intensity) m/z: 428 ([M + 1] 20), 341 (38), 320 (26), 281 (52), 253 (38), 207 (100), 147 (23), 127 (28), 73 (70). Anal. Calcd for $C_{25}H_{16}O_2Se$: C 70.26, H 3.77. Found: C 70.39, H 3.82.

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3-Butyl-4-(phenylselenyl)-1*H*-isochromen-1-one (2h). Yield: 0.066 g (74%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.28 (dd, J = 7.8 Hz, J = 1.0 Hz, 1H), 7.97−7.91 (m, 1H), 7.70−7.61 (m, 1H), 7.50−7.42 (m,1H), 7.25−7.15 (m, 5H), 3.04 (t, J = 7.5 Hz, 2H), 1.68 (quint, J = 7.6 Hz, 2H), 1.41 (sext, J = 7.6 Hz, 2H), 0.90 (t, J = 7.2 Hz, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 163.8, 162.0, 138.3, 135.2, 131.3, 129.5, 129.4, 128.7, 127.9, 127.3, 126.4, 120.4, 104.1, 34.4, 30.1, 22.3, 13.7. MS (relative intensity) m/z: 358 ([M + 1] 59), 274 (51), 193 (39), 165 (100), 131 (54), 91 (47), 85 (52), 57 (91). Anal. Calcd for $C_{19}H_{18}O_2Se$: C 63.87, H 5.08. Found: C 63.65, H 5.02.

4-(4-Chlorophenylselenyl)-3-phenyl-1*H*-isochromen-1-one (2i). Yield: 0.082 g (80%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.36 (dd, J = 7.8 Hz, J = 1.0 Hz, 1H), 8.02−7.97 (m, 1H), 7.76−7.50 (m, 4H), 7.46−7.35 (m, 3H), 7.18−7.07 (m, 4H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.5, 159.7, 138.0, 135.4, 133.8, 132.6, 130.2, 130.1, 129.9, 129.8, 129.6, 129.5, 128.8, 127.9, 127.8, 120.8, 104.5. MS (relative intensity) m/z: 412 ([M + 1] 8), 304 (4), 193 (6), 165 (14), 105 (100), 77 (22). Anal. Calcd for $C_{21}H_{13}ClO_2Se$: C 61.26, H 3.18. Found: C 61.42, H 3.22.

4-(4-Fluorophenylselenyl)-3-phenyl-1*H*-isochromen-1-one (2j). Yield: 0.072 g (73%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.35 (dd, J = 7.8 Hz, J = 1.0 Hz, 1H), 8.07−8.03 (m,1H), 7.77−7.50 (m, 4H), 7.47−7.36 (m, 3H), 7.21−7.10 (m, 1H), 6.96−6.82 (m, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.9 (d, $^1J_{CF}$ = 246.6 Hz), 161.5, 159.5, 138.2, 135.3, 133.9, 131.2 (d, $^3J_{CF}$ = 8.0 Hz), 130.1, 128.7, 128.0, 127.8, 125.9, 125.2, 120.8, 116.6 (d, $^2J_{CF}$ = 21.9 Hz), 105.4, 101.7. MS (relative intensity) m/z: 396 ([M + 1] 12), 288 (8), 193 (7), 165 (16), 105 (100), 77 (23). Anal. Calcd for $C_{21}H_{13}FO_2Se$: C 63.81, H 3.31. Found: C 63.67, H 3.27.

3-Phenyl-4-(*p*-tolylselenyl)-1*H*-isochromen-1-one (2k). Yield: 0.066 g (68%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.37 (dd, J = 7.7 Hz, J = 1.0 Hz, 1H), 7.95−7.91 (m, 1H), 7.73−7.62 (m, 3H), 7.57−7.36 (m, 4H), 7.17−6.92 (m, 4H), 2.35 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.7, 159.6, 138.4, 136.4, 135.4, 133.9, 130.3, 130.1, 129.6, 129.5, 128.7, 128.2, 127.7, 127.0, 126.1, 120.8, 103.9, 21.2. MS (relative intensity) m/z: 392 ([M + 1] 24), 284 (5), 222 (9), 193 (13), 165 (27), 105 (100), 77 (30). Anal. Calcd for $C_{22}H_{16}O_2Se$: C 67.52, H 4.12. Found: C 67.60, H 4.20.

4-(Butylselenyl)-3-phenyl-1*H*-isochromen-1-one (2l). Yield: 0.067 g (76%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.40−8.31 (m,1H), 8.29−8.21 (m, 1H), 7.88−7.79 (m, 1H), 7.72−7.67 (m, 2H), 7.60−7.52 (m, 1H), 7.48−7.43 (m, 3H), 2.55 (t, J = 7.2 Hz, 2H), 1.40 (quint, J = 7.2 Hz, 2H), 1.16 (sext, J = 7.4 Hz, 2H), 0.74 (t, J = 7.2 Hz, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.8, 157.9, 138.9, 135.1, 134.3, 130.1, 129.8, 129.7, 128.4, 128.1, 127.6, 120.7, 105.0, 31.5, 28.7, 22.4, 13.3. MS (relative intensity) m/z: 358 ([M + 1] 38), 302 (18), 245 (14), 193 (100), 165 (59), 105 (75), 77 (64). HRMS calcd for $C_{19}H_{18}O_2Se$: 358.0472. Found: 358.0491.

4-(Ethylselenyl)-3-phenyl-1*H*-isochromen-1-one (2m). Yield: 0.070 g (85%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.35 (dd, J = 7.8 Hz, J = 1.0 Hz, 1H), 8.26−8.22 (m, 1H), 7.86−7.78 (m, 1H), 7.71−7.64 (m, 2H), 7.59−7.51 (m, 1H), 7.48−7.43 (m, 3H), 2.56 (q, J = 7.4 Hz, 2H), 1.16 (t, J = 7.4 Hz, 3H). ^{13}C NMR ($CDCl_3$, 50 MHz): δ 161.8, 157.9, 138.8, 135.1, 134.2, 130.0, 129.7, 129.6, 128.4, 128.0, 127.6, 120.5, 104.7, 22.3, 14.9. MS (relative intensity) m/z: 330 ([M + 1] 47), 301 (10), 273 (10), 245 (12), 193 (100), 165 (30), 105 (14), 77 (25). Anal. Calcd for $C_{17}H_{14}O_2Se$: C 62.01, H 4.29. Found: C 62.30, H 4.42.

3-Butyl-4-(butylselenyl)-1*H*-isochromen-1-one (2n). Yield: 0.056 g (67%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.28 (dd, J = 7.9 Hz, J = 1.1 Hz, 1H), 8.14−8.09 (m, 1H), 7.81−7.72 (m, 1H), 7.52−7.44 (m, 1H), 3.05 (t, J = 7.8 Hz, 2H), 2.68 (t, J = 7.3 Hz, 2H), 1.79−1.25 (m, 8H), 0.99−0.84 (m, 6H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.3, 162.2, 138.8, 134.9, 129.5, 127.6, 127.3, 120.3, 104.1, 34.2, 32.1, 30.2, 28.3, 22.8, 22.3, 13.8, 13.4. MS (relative intensity) m/z: 338 ([M + 1] 100), 282 (37), 240 (19), 202 (25), 197 (67), 159 (60), 85 (71), 57 (49). HRMS calcd for $C_{17}H_{22}O_2Se$: 361.0682 [M + Na], found 361.0705.

7-Methyl-3-phenyl-4-(phenylselenyl)-1*H*-isochromen-1-one (2o). Yield: 0.073 g (75%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.16−8.13 (m, 1H), 7.94−7.90 (m, 1H), 7.68−7.63 (m, 2H), 7.53−7.34 (m, 4H), 7.21−7.16 (m, 5H), 2.47 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.9, 158.6, 139.1, 136.6, 135.9, 134.0, 131.9, 129.9, 126.3, 125.0, 120.6, 104.6, 21.1. MS (relative intensity) m/z: 392 ([M + 1] 8), 341 (10), 284 (17), 253 (10), 207 (45), 178 (25), 105 (100), 77 (18). Anal. Calcd for $C_{22}H_{16}O_2Se$: C 67.52, H 4.12. Found: C 67.65, H 4.20.

4-(4-Chlorophenylsenenyl)-7-methyl-3-phenyl-1*H*-isochromen-1-one (2p). Yield: 0.076 g (72%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.18−8.15 (m, 1H), 7.90−7.84 (m, 1H), 7.65−7.59 (m, 2H), 7.55−7.50 (m, 1H), 7.47−7.34 (m, 3H), 7.17−7.06 (m, 4H), 2.48 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.5, 159.0, 139.2, 136.5, 135.8, 134.0, 132.7, 130.4, 130.1, 130.0, 129.7, 129.6, 129.5, 127.9, 127.8, 120.1, 104.7, 21.1. MS (relative intensity) m/z: 426 ([M + 1] 8), 318 (5), 207 (7), 178 (14), 105 (100), 77 (20). HRMS calcd for $C_{22}H_{15}ClO_2Se$: 429.0369 [M + Na], found 428.0633 [M − 1].

7-Methyl-3-phenyl-4-(*p*-tolylselenyl)-1*H*-isochromen-1-one (2q). Yield: 0.075 g (74%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.17−8.13 (m, 1H), 7.84−7.78 (m, 1H), 7.66−7.62 (m, 2H), 7.51−7.31 (m, 4H), 7.16−6.88 (m, 4H), 2.47 (s, 3H), 2.34 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.7, 158.7, 139.1, 136.5, 136.1, 134.2, 132.7, 130.2, 129.9, 129.6, 129.4, 128.2, 127.7, 126.9, 126.2, 120.8, 104.2, 21.2, 21.1. MS (relative intensity) m/z: 406 ([M + 1] 24), 301 (6), 236 (13), 207 (16), 178 (27), 105 (100), 77 (30). Anal. Calcd for $C_{23}H_{18}O_2Se$: C 68.15, H 4.48. Found: C 68.33, H 4.52.

4-(Methylthio)-3-phenyl-1*H*-isochromen-1-one (2r). Yield: 0.043 g (65%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.37 (dd, J = 7.8 Hz, J = 1.0 Hz, 1H), 8.28−8.21 (m, 1H), 7.92−7.74 (m, 3H), 7.62−7.55 (m, 1H), 7.51−7.46 (m, 3H), 2.17 (s, 3H). ^{13}C NMR ($CDCl_3$,100 MHz): δ 161.5, 158.0, 138.0, 135.2, 133.1, 130.0, 129.9, 129.7, 128.4, 127.8, 125.5, 120.9, 110.9,18.9. MS (relative intensity) m/z: 268 (100), 225 (69), 197 (95), 165 (33), 120 (38), 105 (44), 77 (81). Anal. Calcd for $C_{16}H_{12}O_2S$: C 71.62, H 4.51. Found: C 71.85, H 4.59.

3-Phenyl-4-(phenyltellurenyl)-1*H*-isochromen-1-one (2s). Yield: 0.080 g (75%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.38−8.29 (m, 1H), 8.14−8.06 (m, 1H), 7.74−7.66 (m, 1H), 7.57−7.34 (m, 8H), 7.21−7.07 (m, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.1, 161.4, 139.7, 136.3, 135.4, 135.0, 132.7, 130.0, 129.8, 129.7, 129.6, 128.7, 127.7, 127.5, 120.5, 115.5, 93.7. MS (relative intensity) m/z: 428 ([M + 2] 19), 298 (22), 270 (14), 193 (37), 165 (90), 105 (100), 77 (66). HRMS calcd for $C_{21}H_{14}O_2Te$: 448.9823 [M + Na], found 447.9901 [M − 1].

4-(Butyltellurenyl)-3-phenyl-1*H*-isochromen-1-one (2t). Yield: 0.035 g (35%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.35−8.33 (m, 1H), 8.18−8.16 (m, 1H), 7.82−7.78 (m, 1H), 7.60−7.58 (m, 2H), 7.56−7.52 (m, 1H), 7.46−7.41 (m, 3H), 2.58 (t, J = 7.3 Hz, 2H), 1.50 (quint, J = 7.6 Hz, 2H), 1.18 (sext, J = 7.3 Hz, 2H), 0.77 (t, J = 7.3 Hz, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.3, 159.7, 140.3, 136.4, 135.3, 132.7, 130.1, 129.8, 129.7, 128.5, 127.6, 120.3, 90.3, 33.0, 24.6, 13.2, 9.8. MS (relative intensity) m/z: 406 (23), 222 (59), 193 (100), 165 (52), 105 (13), 77 (20), 57 (5). HRMS calcd for $C_{19}H_{18}O_2Te$: 431.0266 [M + Na], found 431.0295.

General Procedure for 3-Substituted Isochromen-1-ones. In a Schlenk tube, under air, containing CH_2Cl_2 (4 mL) were added $FeCl_3$ (0.041 g, 1 equiv, 99.99% purity from commercial suppliers) and 2-alkynylaryl esters (0.25 mmol) in CH_2Cl_2 (1 mL), and the reaction mixture was stirred overnight at room temperature. After this, the mixture was diluted with dichlorometane (20 mL) and washed with a saturated solution of NH_4Cl (20 mL). The organic phase was separated, dried over $MgSO_4$, and concentrated under vacuum. The residue was purified by flash chromatography and eluted with mixture of hexane/acetate (95:5).

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3-Phenyl-1*H*-isochromen-1-one (3a). Yield: 0.046 g (84%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.32−8.27 (m, 1H), 7.89−7.83 (m, 2H), 7.75−7.67 (m, 1H), 7.52−7.41 (m, 5H), 6.95 (s, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.2, 153.6, 137.5, 134.8, 131.9, 129.9, 129.6, 128.7, 128.0, 125.9, 125.2, 120.5, 101.7. MS (relative intensity) *m*/*z*: 222 (100), 194 (88), 165 (73), 105 (23), 89 (20), 77 (30). Anal. Calcd for $C_{15}H_{10}O_2$: C 81.07, H 4.54. Found: C 81.25, H 4.59.

3-*p*-Tolyl-1*H*-isochromen-1-one (3b). Yield: 0.046 g (79%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.31−8.26 (m,1H), 7.78−7.65 (m, 3H), 7.50−7.43 (m, 2H), 7.27−7.23 (m, 2H), 6.89 (s, 1H), 2.39 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.3, 153.8, 140.2, 137.7, 134.7, 129.6, 129.5, 129.2, 127.8, 125.8, 125.1, 120.4, 101.0, 21.3. MS (relative intensity) *m*/*z*: 236 (100), 208 (96), 193 (38), 178 (16), 165 (44), 119 (14), 91 (27), 89 (30). Anal. Calcd for $C_{16}H_{12}O_2$: C 81.34, H 5.12. Found: C 81.59, H 5.19.

3-(4-Methoxyphenyl)-1*H*-isochromen-1-one (3c). Yield: 0.050 g (80%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.32−8.27 (m, 1H), 7.87−7.79 (m, 2H), 7.74−7.66 (m, 1H), 7.50−7.42 (m, 2H), 7.01−6.94 (m, 2H), 6.84 (s, 1H), 3.87 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.5, 153.7, 137.9, 134.8, 129.6, 127.6, 126.8, 125.6, 124.6, 120.2, 114.2, 100.2, 55.4. MS (relative intensity) *m*/*z*: 252 (100), 224 (96), 181 (82), 152 (51), 135 (9), 89 (25), 77 (21). HRMS calcd for $C_{16}H_{12}O_3$: 252.0786, found 252.0809.

3-(2-Methoxyphenyl)-1*H*-isochromen-1-one (3d). Yield: 0.053 g (84%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.31−8.27 (m, 1H), 7.99−7.95 (m, 1H), 7.74−7.66 (m, 1H), 7.51−7.34 (m, 4H), 7.11−6.98 (m, 2H), 3.96 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.5, 157.2, 150.5, 138.0, 134.6, 130.7, 129.3, 128.8, 127.9, 126.2, 120.8, 120.6, 11.4, 106.9, 55.6. MS (relative intensity) *m*/*z*: 252 (100), 224 (49), 181 (49), 152 (35), 118 (18), 89 (24), 77 (22). HRMS calcd for $C_{16}H_{12}O_3$: 252.0786, found 252.0799.

3-(4-Chlorophenyl)-1*H*-isochromen-1-one (3e). Yield: 0.040 g (63%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.31−8.27 (m,1H), 7.84−7.68 (m, 3H), 7.55−7.39 (m, 4H), 6.93 (s, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.1, 152.5, 137.2, 135.9, 134.9, 130.4, 129.7, 129.1, 128.3, 126.4, 126.0, 120.5, 102.0. MS (relative intensity) *m*/*z*: 256 (100), 230 (26), 228 (81), 193 (64), 165 (52), 139 (24), 111 (25), 89 (22), 82 (25). Anal. Calcd for $C_{15}H_9ClO_2$: C 70.19, H 3.53. Found: C 70.35, H 3.60.

3-(4-Fluorophenyl)-1*H*-isochromen-1-one (3f). Yield: 0.036 g (60%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.32−8.29 (m, 1H), 7.91−7.84 (m, 2H), 7.77−7.69 (m, 1H), 7.54−7.47 (m, 2H), 7.21−7.10 (m,2H), 6.89 (s, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 163.5 (d, $^1J_{CF}$ = 251.0 Hz), 162.1, 152.8, 137.5, 134.9, 129.7, 128.3 (d, $^4J_{CF}$ = 3.2 Hz), 128.2, 127.3 (d, $^3J_{CF}$ = 8.0 Hz), 125.9, 120.5, 115.9 (d, $^2J_{CF}$ = 21.9 Hz), 101.5. MS (relative intensity) *m*/*z*: 240 (95), 212 (96), 183 (100), 123 (26), 106 (10), 95 (32), 75 (10), 63 (10). Anal. Calcd for $C_{15}H_9FO_2$: C 75.00, H 3.78. Found: C 75.25, H 3.82.

3-(Naphthalen-1-yl)-1*H*-isochromen-1-one (3g). Yield: 0.046 g (68%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.40−8.36 (m, 1H), 8.27−8.22 (m, 1H), 7.97−7.89 (m, 2H), 7.81−7.73 (m, 2H), 7.60−7.50 (m, 5H), 6.82 (s, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.6, 154.7, 137.4, 134.9, 133.7, 130.8, 130.7, 130.5, 129.7, 128.6, 128.4, 127.7, 127.1, 126.3, 125.8, 125.1, 125.0, 120.5, 107.1. MS (relative intensity) *m*/*z*: 272 (100), 244 (96), 215 (63), 127 (34), 107 (22), 89 (12). Anal. Calcd for $C_{19}H_{12}O_2$: C 83.81, H 4.44. Found: C 84.01, H 4.50.

3-Butyl-1*H*-isochromen-1-one (3h). Yield: 0.024 g (48%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.27−8.23 (m, 1H), 7.71−7.63 (m, 1H), 7.48−7.27 (m, 2H), 6.26 (s, 1H), 2.53 (t, *J* = 7.7 Hz, 2H), 1.70 (quint, *J* = 7.3 Hz, 2H), 1.40 (sext, *J* = 7.6 Hz, 2H), 0.95 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 163.0, 158.3, 137.7, 134.6, 129.4, 127.4, 124.7, 120.1, 102.8, 33.2, 28.9, 22.1, 13.7. MS (relative intensity) *m*/*z*: 202 (28), 160 (33), 131 (21), 118 (100), 89 (28), 63 (7). HRMS calcd for $C_{13}H_{14}O_2$: 225.0891 [M + Na], found 224.1009 [M − 1].

7-Methyl-3-phenyl-1*H*-isochromen-1-one (3i). Yield: 0.038 g (65%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.10 (s, 1H), 7.88−7.84 (m, 2H), 7.55−7.37 (m, 5H), 6.93 (s, 1H), 2.46 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.5, 152.8, 138.5, 136.1, 135.0, 132.1, 129.7, 129.3, 128.7, 125.8, 125.1, 120.4, 101.7, 21.3. MS (relative intensity) *m*/*z*: 236 (100), 208 (82), 193 (26), 178 (18), 165 (39), 105 (24), 77 (39). Anal. Calcd for $C_{16}H_{12}O_2$: C 81.34, H 5.12. Found: C 81.50, H 5.18.

7-Methyl-3-*p*-tolyl-1*H*-isochromen-1-one (3j). Yield: 0.050 g (81%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.07 (s, 1H), 7.77−7.69 (m, 2H), 7.53−7.46 (m, 1H), 7,35 (d, *J* = 8.0 Hz, 1H), 7.26−7.20 (m, 2H), 6.85 (s, 1H), 2.44 (s, 3H), 2.38 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 165.5, 152.9, 139.9, 138.1, 136.0, 135.2, 129.4, 129.3, 129.2, 125.7, 124.9, 120.2, 100.9, 21.3, 21.2. MS (relative intensity) *m*/*z*: 250 (99), 222 (100), 207 (46), 179 (32), 119 (14), 91 (25). Anal. Calcd for $C_{17}H_{14}O_2$: C 81.58, H 5.64. Found: C 81.75, H 5.70.

7-Methyl-3-(naphthalen-1-yl)-1*H*-isochromen-1-one (3k). Yield: 0.059 g (83%). ^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.25−8.16 (m, 2H), 7.93−7.86 (m, 2H), 7.71 (dd, *J* = 7.2 Hz, *J* = 1.2 Hz, 1H), 7.57−7.46 (m, 4H), 7.38 (d, *J* = 7.9 Hz,1H), 6.75 (s, 1H), 2.48 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.7, 153.7, 138.7, 136.1, 134.9, 133.7, 130.8, 130.6, 130.3, 129.3, 128.5, 127.7, 126.9, 126.1, 125.7, 125.1, 124.9, 120.3, 106.9, 21.4. MS (relative intensity) *m*/*z*: 286 (100), 258 (99), 243 (27), 215 (37), 127 (35), 114 (14), 77 (12). Anal. Calcd for $C_{20}H_{14}O_2$: C 83.90, H 4.93. Found: C 84.17, H 5.01.

3-(4-Methoxyphenyl)-7-methyl-1*H*-isochromen-1-one (3l). Yield: 0.036 g (54%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.00 (s, 1H), 7.80−7.77 (m, 2H), 7.51−7.47 (m, 1H), 7.34 (d, *J* = 7.9 Hz, 1H), 6.96−6.94 (m, 2H), 6.78 (s, 1H), 3.85 (s, 3H), 2.45 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.6, 160.8, 152.8, 137.8, 136.1, 135.4, 129.2, 126.6, 125.6, 124.6, 119.9, 114.2, 100.1, 55.3, 21.3. MS (relative intensity) *m*/*z*: 266 (100), 238 (92), 223 (40), 195 (60), 152 (28), 135 (10), 119 (11), 103 (9), 77 (23). Anal. Calcd for $C_{17}H_{14}O_3$: C 76.68, H 5.30. Found: C 76.81, H 5.38.

■ ASSOCIATED CONTENT

Supporting Information. ^{1}H and ^{13}C NMR spectra for all reaction products and X-ray data tables and CIF files for **2a**. This material is available free of charge via the Internet at http://pubs.acs.org.

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