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Ultrasound and Oxone® promoting regioselective selenofunctionalization of chromone

Daniela R. Araujo, Yanka R. Lima, Angelita M. Barcellos, Raquel G. Jacob, Márcio S. Silva, and Gelson Perin*

Address: Laboratório de Síntese Orgânica Limpa – LASOL, Federal University of Pelotas – UFPel, P.O. Box 354, 96010-900, Pelotas – RS, Brazil
Email: gelson_perin@ufpel.edu.br

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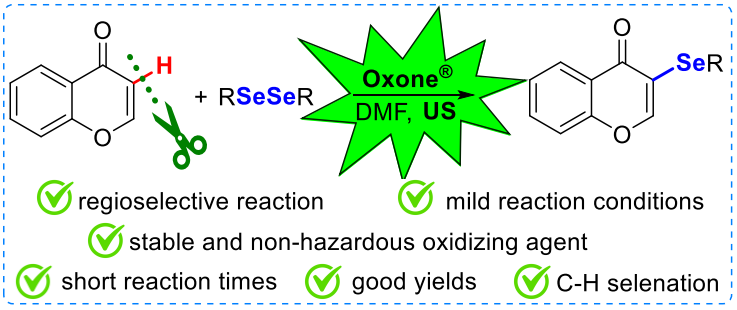
Abstract

Selective, simple and green synthetic procedures constitute an important goal in organic synthesis. In this sense, we describe the synthesis of 3-(organylselanyl)-4*H*-chromen-4-ones by regioselective selenofunctionalization of the chromone core using diorganyl diselenides. These reactions were efficiently conducted under mild conditions, employing Oxone® as stable and non-hazardous oxidizing agent in the presence of ultrasound in short reaction times. By this efficient approach, eight new compounds were obtained in moderate to excellent yields.



Keywords: Chromone, organochalcogen, Oxone®, selenium, ultrasound

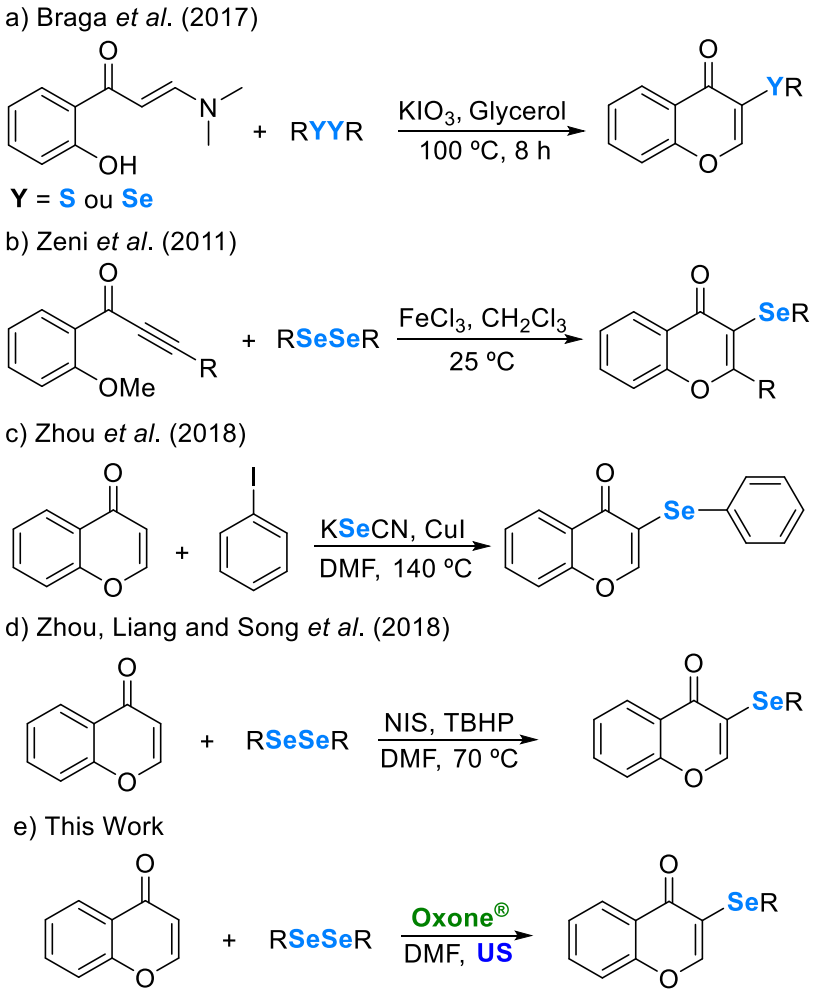
Introduction

Organochalcogen compounds have been widely studied by the scientific community based on their antioxidant activity related to biological properties which are well described in the literature.[1] In the last decades there has been a growing interest in the synthesis of these compounds, specifically organoselenium compounds, due to their promising biological applications, such as antifungal,[2] antibacterial[3] and antiviral.[4] Indeed, selenium is recognized as an essential micronutrient of particular interest because of its ability to participate in crucial redox reactions that are implicated in antioxidant,[5] chemopreventive[6] or apoptotic activities.[7] In addition, the chemical modification of natural compounds is of utmost strategic importance, considering the intention of increasing or improving the biological activities already present in the original molecule. In this sense, the selenium-containing citronellal derivatives caused the potentiation of the antioxidant activity of this natural compound,[8] the insertion of selenium in the structure of sugars[9] and the selenofunctionalization of a flavonoid, chrysin, enhanced the antioxidant and anticancer activities.[10]

Another class of compounds, which play an important role in drug discovery, are the heterocyclics, among which are flavonoids.[11] Flavonoids are natural polyphenolic phytochemicals that can be found in many fruits and vegetables, and are usually present in the human diet.[10] Specifically, chromones are of synthetic interest, not only due to their natural occurrence, which makes them ubiquitous in nature, but also because of their amphoteric character and low toxicity to mammalians.[12] Molecules containing the chromone core have a wide range of biological activities including tyrosine and protein kinase C inhibitors,[13] anticancer agents[14] and antimalarial.[15] Many of these biological actions are attributed to the ability to transfer electrons, activate antioxidant enzymes,[16] reduce α-tocopherol radicals,[17] chelate metal catalysts[18] and inhibit oxidases.[19] Few methods are found to obtain chromones containing an organochalcogen moiety. For example, Braga et al.[20] described the cyclization of enaminones with diorganyl dichalcogenides (Scheme 1a). In 2011, Zeni et al.[21] reported the intramolecular cyclization reaction using $FeCl_3$/RSeSeR as cyclizing agent to prepare these chromone derivatives (Scheme 1b). More recently, the chromone core was functionalized by KSeCN *via* copper catalysis (Scheme 1c)[22] or by the direct NIS and TBHP-induced C-H functionalization employing diselenides as starting materials (Scheme 1d) .[23]

In parallel, our group has studied the application of Oxone® as an oxidizing agent in some organochalcogen compound transformations.[24] More specifically, we demonstrated its application in the carbocyclization of alkynols for the synthesis of 2-organoselanyl naphthalenes,[25] in the synthesis of 1*H*-pyrazole[26] and of isochromenones fused to selenophenes.[27] Our interest in Oxone® is due to advantages as being non-toxic, easy to handle, bench stable solid and it has a low cost.[28]

Additionally, in order to minimize the energy used in chemical processes, several procedures have been described using ultrasound irradiation.[29] The use of ultrasound in organic synthesis is linked to the phenomenon of acoustic cavitation and it was used in the synthesis of selanylindoles,[30] selanylimidazopyridines,[31] alkali metals diselenides[32] and in the functionalization of chrysin,[33] for example. Therefore, based on what was previously mentioned, the aim of this work was to combine these two moieties by the regioselective selenofunctionalization of the chromone core **1** using diorganyl diselenides **2** and Oxone® as oxidizing agent to obtain the respective 3-(organylselanyl)-4*H*-chromen-4-ones **3** (Scheme 1e).



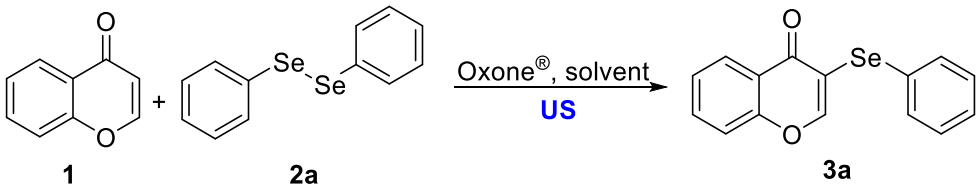
Scheme 1

Results and Discussion

Initially, in order to obtain the desired product 3-(phenylselanyl)-4*H*-chromen-4-one (**3a**), a first test was performed through the use of 0.250 mmol chromone **1**, 0.125 mmol diselenide **2a**, 0.250 mmol Oxone® and dimethylformamide (DMF, 2.0 mL) as solvent in a conventional system at 50 °C. After 24 h, the total consumption of the starting materials was observed (monitored by TLC), and the desired product **3a** was isolated in 76% yield (Table 1, entry 1). To our satisfaction, this condition promoted the regioselective selenofunctionalization in the position 3 of the chromone core, by verification using 2D NMR techniques (See Support Information). In order to shorten the reaction time and possibly increase the yield of the desired product by using an alternative energy source, the ultrasound probe was applied. A test using the same quantities of the reagents was performed. In this test with ultrasound, fortunately a decrease in reaction time occurred from 24 h to 0.8 h, giving the compound **3a** in 86% yield (Table 1, entry 2). Encouraged by this result, a comparative study was carried out to check the influence of different stoichiometric amounts of diselenide **2a** and Oxone®, as well as the best solvent for this synthesis (Table 1, entries 3-12). In order to increase the reaction yield, a reaction was performed using excess of reagent **2a**, however no significant increase in reaction yield occurred (Table 1, entry 3). To verify the importance of Oxone®, two reactions were performed with distinct amounts. In the first one, a small excess was used and in the second one, the amount of Oxone®

was reduced. In both cases, however, the observed results were not satisfactory (Table 1, entries 4 and 5). Additionally, without Oxone® the formation of the product **3a** did not occur, proving the necessity of using this reagent (Table 1, entry 6). After that, the solvent variation study was carried out. When testing EtOH and MeOH, a complex mixture of products was observed and the desired **3a** product was obtained in 68% and 56% yield, respectively (Table 1, entries 7 and 8). Furthermore, using acetonitrile as solvent, the product was obtained in 74% yield (Table 1, entry 9). When the reaction was performed in water, only traces of the product **3a** were observed (Table 1, entry 10). This result can be explained by the lower solubility of the starting materials in polar solvents. The use of alternative green solvents, such as glycerol and polyethylene glycol-400 (PEG-400) was evaluated, however the results were not satisfactory (Table 1, entries 11 and 12). Finally, based on the results depicted in Table 1, the best reaction condition was defined as the sonication of a mixture of 0.250 mmol of chromone **1a**, 0.125 mmol of diphenyl diselenide (**2a**) and 0.250 mmol of Oxone® in DMF as the solvent (2.0 mL) (Table 1, entry 2).

Table 1. Optimization of the reaction conditions[a]



Entry	**2a** (mmol)	Oxone® (mmol)	Time (hours)	Solvent	Yield (%)[d]
1[b]	0.125	0.250	24	DMF	76
2	0.125	0.250	0.8	DMF	86
3[c]	0.250	0.250	0.8	DMF	85
4	0.125	0.300	0.8	DMF	80
5	0.125	0.125	1.5	DMF	41
6	0.125	-	1.0	DMF	NR
7	0.125	0.250	1.0	EtOH	68
8	0.125	0.250	1.5	MeOH	56
9	0.125	0.250	1.5	MeCN	74
10	0.125	0.250	2.0	H_2O	Traces
11	0.125	0.250	1.4	Glycerol	59
12	0.125	0.250	1.5	PEG-400	47

[a]A mixture of **1** (0.250 mmol), **2a**, Oxone® and the solvent (2.0 mL) in a glass tube was sonicated at 60% of amplitude for the time indicated. [b]Reaction under conventional heating of 50 °C. [c]It was used 0.250 mmol of **2a**. [d]Isolated yields after column chromatography. NR: no reaction.

Once the best conditions were determined, the method was extended to different substrates, in order to evaluate its generality and robustness in the synthesis of different 3-(organoselanyl)-4*H*-chromen-4-ones **3** (Table 2). The effect of electron-withdrawing groups (EWG) and electron-donor ones (EDG) attached to the aromatic ring of the diaryl diselenide **2** was evaluated in the reaction with chromone **1** (Table 2, entries 1-6). In general, there was no significant difference in yield when diaryl diselenides containing electron-deficient and electron-rich were used, leading to the formation of all desired products in good yields. For example, when diaryl diselenides attached in *para* position with electron-donor groups **2b** (R = 4-CH_3) and **2c** (R = 4-CH_3O)

were used, the respective products **3b** and **3c** were obtained in 78% and 80% yields after 0.6 and 0.7 h, respectively (Table 2, entries 2 and 3). Similarly, good yields and short reaction times were observed when the reaction proceeded with electron-deficient diaryl diselenides **2d** (R = 4-Cl), **2e** (R = 4-F) and **2f** (R = 3-CF_3). The respective products were isolated in 87%, 72% and 82% yields, after 0.5 to 0.6 h of reaction time (Table 2, entries 4-6).

Table 2. Synthesis of 3-(organochalcogenyl)-4*H*-chromen-4-ones **3a**-**k**[a]

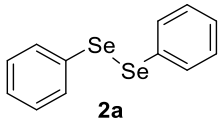
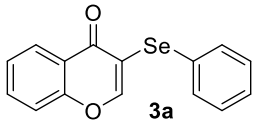
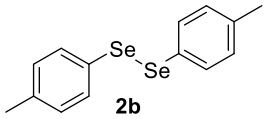
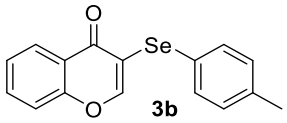
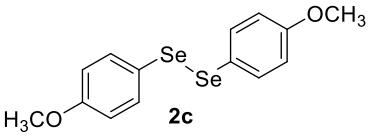
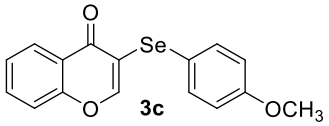
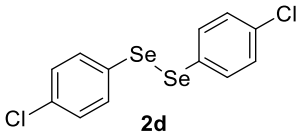
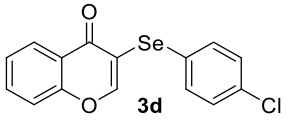
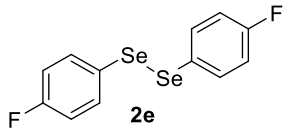
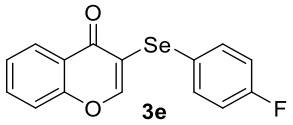
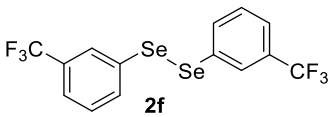
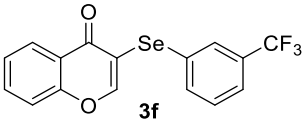
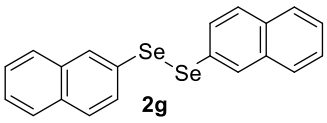
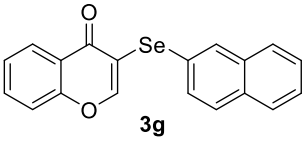
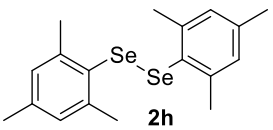
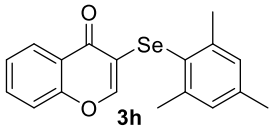
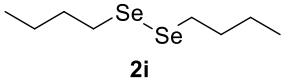
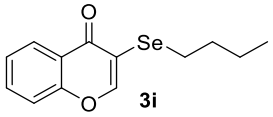
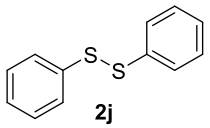
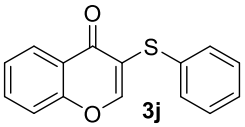
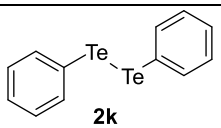
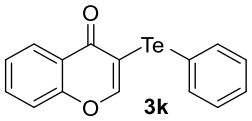
Entry	Dichalcogenide **2**	Product **3**	Time (h)	Yield[b] (%)
1	 **2a**	 **3a**	0.8	86
2	 **2b**	 **3b**	0.6	78
3	 **2c**	 **3c**	0.7	80
4	 **2d**	 **3d**	0.5	87
5	 **2e**	 **3e**	0.5	72
6	 **2f**	 **3f**	0.6	82
7	 **2g**	 **3g**	0.5	74
8	 **2h**	 **3h**	0.5	82
9	 **2i**	 **3i**	2.0	NR

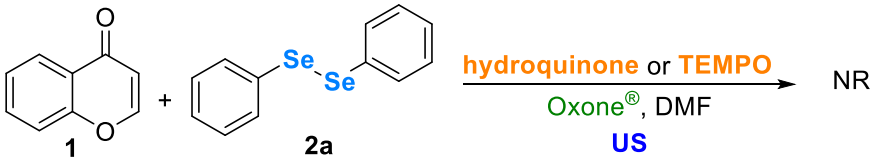
Table 2. Continued

Entry	Dichalcogenide **2**	Product **3**	Time (h)	Yield[b] (%)
10	 **2j**	 **3j**	2.0	NR
11	 **2k**	 **3k**	2.0	NR

[a]A mixture of chromone **1** (0.250 mmol), **2** (0.125 mmol), Oxone® and DMF (2.0 mL) in a glass tube was sonicated at 60% of amplitude for the time indicated. [b]Isolated yields after column chromatography. NR: no reaction.

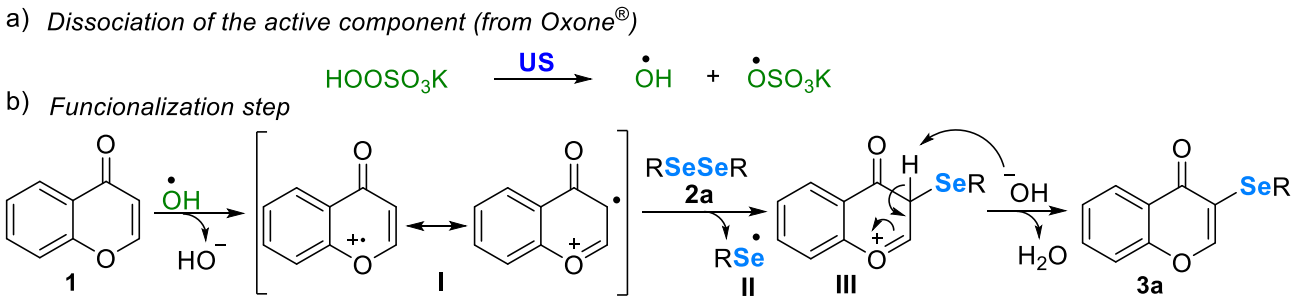
The voluminous groups 2-naphthyl (**2g**) and mesityl (**2h**) were also suitable substrates for the reaction, affording the expected products **3g** and **3h** in 74% and 82% yields respectively, after 0.5 h (Table 2, entries 7 and 8). When we tried to apply the method to alkyl-substituted dibutyl diselenide **2i**, unfortunately the desired product **3i** was not obtained, even after 2 h of reaction, and only the presence of starting materials was observed (monitored by TLC) (Table 2, entry 9). Finally, the substrate scope was extended to other dichalcogenides using diphenyl disulfide (**2j**) and diphenyl ditelluride (**2k**), but only oxidation products of the starting materials were observed, and the desired products **3j** and **3k** were not obtained (Table 2, entries 10 and 11).

To propose a reaction mechanism for this synthesis, control experiments were carried out. The formation of radical intermediates was verified, by performing the reaction in the presence of two radical scavengers. When 3.0 equivalents of hydroquinone or 2,2,6,6-tetramethylpiperidin-1-oxyl (TEMPO) were used, the product **3a** was not obtained, even after 2 h of reaction (Scheme 2 and See Support Information). With the results obtained in these tests, it was suggested that the reaction mechanism involves a radical pathway.



Scheme 2

Based on the literature[23,34,35] and in our own results, a plausible mechanism for the formation of 3-(organoselanyl)-4*H*-chromen-4-one **3** was proposed (Scheme 3). The first step is the formation of $HO^{\bullet}$ and $KSO_4^{\bullet}$ from the US-promoted dissociation of Oxone® (Scheme 3a). The second step is a single electron transfer (SET) from **1** to hydroxyl radical form the intermediate **I**. Then, the formation of the selenide radical **II** and the selenylated flavone cation **III** occur from the reaction of intermediate **I** with the diselenide **2a**. Finally, the deprotonation of intermediate **III** provides the product **3a** (Scheme 3b).



Scheme 3

Conclusions

We demonstrate here the regioselective selenofunctionalization of the chromone core using diselenides, Oxone® and DMF as solvent. To form the 3-(organylselanyl)-4*H*-chromen-4-ones, the reaction was carried out in the presence of ultrasound, which caused a reduction in the reaction times and good yields. The method allowed the use of several diaryl diselenides, providing eight new compounds in a regioselective way under mild conditions.

Experimental Section

General. The reactions were monitored by TLC carried out on Merck silica gel (60 F_{254}) by using UV light as visualizing agent and 5% vanillin in 10% H_2SO_4 and heat as developing agents. Baker silica gel (particle size 0.040-0.063 mm) was used for flash chromatography. The nuclear magnetic resonance (NMR) analyses were carried out in a Bruker Avance III HD spectrometer employing a direct broadband observe probe (F-BBO). Hydrogen nuclear magnetic resonance spectra (^{1}H NMR) were obtained at 400 MHz. Spectra were recorded in deuterated DMSO-d_6 solutions. ^{1}H NMR Chemical shifts are reported in ppm, referenced to tetramethylsilane (TMS) as the internal reference (0.0 ppm). Coupling constant (*J*) are reported in Hertz (Hz). Abbreviations to denote the multiplicity of a signal are s (singlet), d (doublet), dd (doublet of doublet) and m (multiplet). Carbon-13 nuclear magnetic resonance spectra (^{13}C-{^{1}H} NMR) were obtained at 100 MHz. ^{13}C NMR Chemical shifts are reported in ppm, referenced to tetramethylsilane (TMS) as the internal reference (0.0 ppm). Selenium-77 nuclear magnetic resonance spectra (^{77}Se-{^{1}H} NMR) were obtained at 76.0 MHz. The ^{77}Se NMR chemical shifts are reported in ppm relative to external standard, the $C_6H_5SeSeC_6$ in $CDCl_3$ (δ 463 ppm). Low-resolution mass spectra (MS) were obtained with a Shimadzu GC-MS-QP2010 mass spectrometer. The HRMS analyses were performed in a Bruker micrOTOF-QII spectrometer equipped with an APCI source operating in positive mode. The samples were solubilized in acetonitrile and analyzed by direct infusion. The ultrasound-promoted reactions were performed using a Cole Parmer-ultrasonic processor Model CPX 130, with a maxim power of 130 W, operating at amplitude of 60% and a frequency of 20 kHz. The temperature of the reaction under US was monitored using an Incoterm digital infrared thermometer Model Infraterm (Brazil). Melting point (mp) values were measured in a Marte PFD III instrument with a 0.1 °C precision. Oxone® was purchased from Sigma Aldrich.

General procedure for synthesis of 3-(phenylselanyl)-4*H*-chromen-4-ones 3. To a 10 mL round-bottomed glass vial, the chromone **1** (0.250 mmol), diselenide **2a**-**h** (0.125 mmol), Oxone® (0.077 g; 0.250 mmol) and DMF (2.0 mL) were added. The US probe was placed in the reaction vial, which was sonicated (20 KHz, 60% of sonic amplitude) for the time indicated in Table 2. The reaction progress was monitored by TLC in order to evaluate the starting materials consumption. After that, the reaction mixture was extracted with ethyl acetate (3x 15.0 mL), the organic phase was separated, dried over $MgSO_4$ and the solvent was evaporated under reduced pressure. The product was isolated by column chromatography using silica gel 60Å (0.060-0.200 mm-Across) and using a mixture of hexane and ethyl acetate (90:10).

3-(Phenylselanyl)-4*H*-chromen-4-one (3a).[20] Yield: 0.065 g (86%); white solid, m.p.: 65-66 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ (ppm) = 8.56 (s, 1H); 8.05 (dd, J = 8.0, 1.7 Hz, 1H); 7.84-7.80 (m, 1H); 7.65 (d, J = 8.0 Hz, 1H); 7.53-7.49 (m, 1H); 7.47-7.44 (m, 2H); 7.31-7.25 (m, 3H). ^{13}C-{^{1}H} NMR (100 MHz, DMSO-d_6) δ (ppm) = 174.1, 159.2, 155.9, 134.5, 131.2, 129.5, 127.2, 126.0, 125.5, 122.7, 118.5, 114.8. ^{77}Se NMR (76 MHz, DMSO-d_6) δ (ppm) = 288.2. MS (rel. int., %) m/z: 302 (M^+, 100.0), 182 (91.5), 165 (21.8), 102 (92.9), 77 (61.9), 51 (59.7).

3-(4-Tolylselanyl)-4*H*-chromen-4-one (3b).[20] Yield: 0.062 g (78%); white solid, m.p.: 87-88 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ (ppm) = 8.47 (s, 1H); 8.05 (d, J = 8.4 Hz, 1H); 7.85-7.81 (m, 1H); 7.66 (d, J = 8.4 Hz, 1H); 7.54-7.51 (m, 1H); 7.39 (d, J = 7.9 Hz, 2H); 7.12 (d, J = 7.9 Hz, 2 H); 2.26 (s, 3H). ^{13}C-{^{1}H} NMR (100 MHz, DMSO-d_6) δ (ppm) = 174.1, 158.2, 155.9, 137.1, 134.5, 132.1, 130.2, 126.0, 125.4, 125.1, 122.6, 118.5, 115.6, 20.6. ^{77}Se NMR (76 MHz, DMSO-d_6) δ (ppm) = 284.9. MS (rel. int., %) m/z: 316 (M^+, 91.2), 235 (100.0), 196 (50.0), 115 (54.6), 91 (30.6), 65 (21.9).

3-[(4-Methoxyphenyl)selanyl]-4*H*-chromen-4-one (3c).[20] Yield: 0.066 g (80%); white solid, m.p.: 93-94 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ (ppm) = 8.25 (s, 1H); 8.04 (dd, J = 8.3, 1.7 Hz, 1H); 7.82-7.80 (m, 1H); 7.63 (d, J = 8.3 Hz, 1H); 7.53-7.49 (m, 3H); 6.93-6.90 (m, 2H); 3.74 (s, 3H). ^{13}C-{^{1}H} NMR (100 MHz, DMSO-d_6) δ (ppm) = 174.1, 159.4, 156.6, 155.8, 135.2, 134.5, 125.9, 125.3, 122.4, 118.4, 117.6, 116.9, 115.3, 55.2. ^{77}Se NMR (76 MHz, DMSO-d_6) δ (ppm) = 276.6. MS (rel. int., %) m/z: 331 (M^+, 90.6), 251 (100.0), 212 (26.9), 132 (39.3), 92 (48.2), 63 (66.8).

3-[(4-Chlorophenyl)selanyl)-4*H*-chromen-4-one (3d).[20] Yield: 0.073 g (87%); white solid, m.p.: 117-118 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ (ppm) = 8.70 (s, 1H); 8.06 (d, J = 8.2 Hz, 1H); 7.87-7.83 (m, 1H); 7.69 (d, J = 8.2 Hz, 1H); 7.56-7.52 (m, 1H); 7.46 (d, J = 8.6 Hz, 2H); 7.33 (d, J = 8.6 Hz, 2H). ^{13}C-{^{1}H} NMR (100 MHz, DMSO-d_6) δ (ppm) = 173.9, 159.9, 155.9, 134.6, 132.6, 131.9, 129.3, 128.6, 126.1, 125.5, 122.8, 118.5, 114.3. ^{77}Se NMR (76 MHz, DMSO-d_6) δ (ppm) = 285.9. MS (rel. int., %) m/z: 336 (M^+, 28.6), 255 (35.3), 155 (9.2), 120 (42.1), 92 (100.0), 50 (53.3).

3-[(4-Fluorophenyl)selanyl)-4*H*-chromen-4-one (3e).[20] Yield: 0.058 g (72%); white solid, m.p.: 83-84 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ (ppm) = 8.55 (s, 1H); 8.05 (d, J = 8.0 Hz, 1H); 7.85-7.81 (m, 1H); 7.66 (d, J = 8.0 Hz, 1H); 7.56-7.52 (m, 3H); 7.17-7.13 (m, 2H). ^{13}C-{^{1}H} NMR (100 MHz, DMSO-d_6) δ (ppm) = 174.0, 161.8 (d, J = 243.2 Hz), 158.7, 155.9, 134.5, 134.2 (d, J = 7.9 Hz), 126.0, 125.4, 124.0 (d, J = 3.4 Hz), 122.7, 118.5, 116.5 (d, J = 21.8 Hz), 115.3. ^{77}Se NMR (76 MHz, DMSO-d_6) δ (ppm) = 291.3. MS (rel. int., %) m/z: 320 (M^+, 27.0), 239 (31.1), 200 (29.6), 120 (100.0), 92 (54.0), 75 (21.1).

3-{[3-(Trifluormethyl)phenyl]selanyl}-4*H*-chromen-4-one (3f).[20] Yield: 0.076 g (82%); white solid, m.p.: 112-113 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ (ppm) = 8.82 (s, 1H); 8.08-8.06 (m, 1H); 7.88-7.84 (m, 1H); 7.80 (s, 1H); 7.72-7.69 (m, 2H); 7.60-7.47 (m, 3H). ^{13}C-{^{1}H} NMR (100 MHz, DMSO-d_6) δ (ppm) = 174.0, 160.7, 156.0, 134.7, 134.4, 131.8, 130.2, 129.8 (q, J = 31.7 Hz), 126.7 (q, J = 3.9 Hz), 126.2, 125.5, 123.8 (q, J = 271.1 Hz), 123.6 (q, J = 3.9 Hz), 122.9, 118.6, 113.6. ^{77}Se NMR (76 MHz, DMSO-d_6) δ (ppm) = 292.5. ^{19}F NMR (376 MHz, DMSO-d_6) δ (62.2. MS (rel. int., %) m/z: 370 (M^+, 10.4), 249 (30.2), 220 (3.9), 120 (100.0), 92 (71.7), 63 (26.8).

3-(Naphthalen-2-ylselanyl)-4*H*-chromen-4-one (3g).[20] Yield: 0.065 g (74%); white solid, m.p.: 68-69 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ (ppm) = 8.32 (s, 1H); 8.24 (d, *J* = 8.2 Hz, 1H); 8.06 (dd, *J* = 7.6, 1.2 Hz, 1H); 7.98-7.96 (m, 1H); 7.92 (d, *J* = 8.2 Hz, 1H); 7.84-7.79 (m, 1H); 7.72 (dd, *J* = 7.6, 1.2 Hz, 1H); 7.52 (m, 4H) 7.44-7.40 (m, 1H). ^{13}C-{^{1}H} NMR (100 MHz, DMSO-d_6) δ (ppm) = 174.2, 158.0, 155.9, 134.6, 133.7, 132.7, 131.8, 128.8, 128.7, 127.3, 127.2, 126.5, 126.3, 126.0, 125.4, 122.5, 118.5, 115.1, 109.5. ^{77}Se NMR (76 MHz, DMSO-d_6) δ (ppm) = 233.6. MS (rel. int., %) *m*/*z*: 352 (M^+, 57.6), 270 (100.0), 253 (18.6), 152 (60.1), 126 (21.7), 77 (17.6).

3-(Mesitylselanyl)-4*H*-chromen-4-one (3h). Yield: 0.071 g (82%); yellowish solid, m.p.: 110-111 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ (ppm) = 8.05 (dd, *J* = 8.0, 1.7 Hz, 1H); 7.83-7.78 (m, 1H); 7.59 (d, *J* = 8.0 Hz, 1H); 7.53-7.49 (m, 1H); 7.43 (s, 1H); 7.05 (s, 2H); 2.45 (s, 6H); 2.26 (s, 3H). ^{13}C-{^{1}H} NMR (100 MHz, DMSO-d_6) δ (ppm) = 174.6, 155.8, 151.6, 143.2, 139.1, 134.4, 129.0, 125.8, 125.1, 123.6, 121.7, 118.4, 117.1, 23.6, 20.6. ^{77}Se NMR (76 MHz, DMSO-d_6) δ (ppm) = 262.1. MS (rel. int., %) *m*/*z*: 344 (M^+, 8.0), 263 (49.4), 235 (17.4), 192 (5.4), 119 (100.0), 77 (43.1). HRMS (APCI-QTOF) calculated mass for $C_{18}H_{17}O_2Se$ $[M+H]^+$: 345.0394, found: 345.0389.

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Supplementary Material

The general procedure for synthesis of 3-(organylselanyl)-4*H*-chromen-4-ones; ^{1}H NMR, ^{13}C NMR and ^{77}Se NMR spectra for compounds **3a**-**e**, **3g**-**h** and for the Control Experiments of Scheme S1; and ^{1}H NMR, ^{13}C NMR, ^{19}F NMR and ^{77}Se NMR for compound **3f** can be found in the online version of the text.

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