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FULL PAPER

Selenomethoxylation of Alkenes Promoted by Oxone®

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Abstract: We describe herein an alternative method for the selenomethoxylation of unactivated alkenes using Oxone® as a stoichiometric oxidant. The electrophilic species of selenium were easily generated *in situ* by the reaction of diorganyl diselenides with Oxone®. By this efficient and simple approach, *β*-methoxy-selenides were obtained in moderate to excellent yields at room temperature in an open flask, starting from alkenes and using methanol as both nucleophile and solvent. When a mixture of H_2O/CH_3CN was the solvent, *β*-hydroxy-selenides were selectively obtained under mild conditions.

Introduction

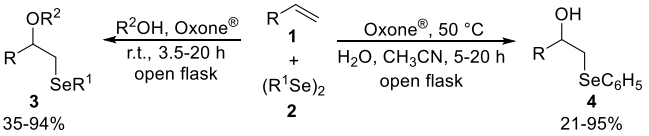
The use of potassium peroxymonosulfate as oxidizing agent in organic synthesis presents many advantages, such as simplicity in handling, stability under several conditions and an environmentally safer disposal, once it is not toxic. Moreover, it is commercially available as Oxone® in the form of a triple salt ($2KHSO_5 \cdot KHSO_4 \cdot K_2SO_4$) containing about 50% of active oxidant/mol, i.e., the anion peroxymonosulfate (HSO_5^-). The active oxidant within the mixture has been efficiently used to perform a great number of organic transformations in polar solvents.[1] More recently, Oxone® was applied in the direct conversion of Baylis-Hillman alcohols to β-chloro aldehydes,[2] the α-amination of ketones through nitroso aldol reaction,[3] the oxidative chlorination of C_{sp3}-H bonds,[4] in C_{sp3}-H hydroxylation[5] and the direct oxidative cascade cyclization of 2-aminobenzoic acid and arylaldehydes.[6] Furthermore, Oxone® was used to prepare different classes of organic compounds, such as indenochromenes,[7] β-fluoroporpholactones,[8] α-bromo- and α-azidoketones.[9]

Regarding its use in the synthesis of organochalcogen compounds,[10] Oxone® was used in the oxidation of sulfides to sulfoxides and sulfones,[11] oxidation of thiols to sulfonic acids,[12] oxyhalogenation of thiols and disulfides,[13] oxidative coupling of thiols to disulfides,[14] oxidation of selenides to selenones[15] and in the enantioselective oxidation of disulfides.[16] Oxone® was used to prepare symmetric thiosulfonates,[17] 3-arylthio indoles[18] and 2-aminobenzothiazoles.[19]

In parallel to the increasing number of applications of Oxone®, studies on the synthesis, use as synthetic intermediate and bioactivity of organoselenides has attracted continuous interest, mainly due to their important role in biological systems.[20] A common synthetic strategy to prepare new organoselenides is the electrophilic addition of an organoselenium group into the chemical structure. Among the alternatives to prepare electrophilic selenium *in situ*, the oxidative cleavage of the Se-Se bond of diorganyl diselenides is a usual approach. Stoichiometric or over-stoichiometric amounts of KBr/*m*-CPBA,[21] $[PhI(OAc)_2]$,[22] I_2/DMSO,[23] $(NH_4)_2S_2O_8$ [24] have been used with this aim.

These reactive electrophiles are useful reagents in the seleno-oxylation of alkenes by the *anti*-1,2-addition of an organoseleno group to the double bond *via* the formation of a seleniranium intermediate, that rapidly reacts with a nucleophilic oxygen (HO or RO). In the literature, it was described the selenoalkoxy- and hydroxylation of alkenes with diselenides promoted by TsOH/*m*-CPBA,[25] NH_4I/*m*-CPBA,[26] *m*-nitrobenzenesulfonyl peroxide,[27] I_2/DMSO,[23] 2,3-dichloro-5,6-dicyanobenzoquinone (DDQ),[28] halide/electrolytic system,[29] $(NH_4)_2S_2O_8$[30] and by ceric ammonium nitrate (CAN).[31]

In continuation to our studies in the development of efficient protocols to prepare functionalized organoselenides, we report herein an alternative method for the selenomethoxy- and selenohydroxylation of alkenes using Oxone® as an oxidant. This method involves the reaction of alkenes **1** with electrophilic selenium generated *in situ*, through the reaction of diorganoyl diselenides **2** with Oxone® in methanol or aqueous medium under mild conditions, to prepare *β*-methoxy-selenides **3** and *β*-hydroxy-selenides **4**, respectively (Scheme 1).



3 35-94% **4** 21-95%

R = alkyl, aryl; R^2 = CH_3, C_2H_5

R^1 = C_6H_5, 4-$CH_3C_6H_4$, 4-$CH_3OC_6H_4$, 4-ClC_6H_4, 2,4,6-$(CH_3)_3C_6H_2$, C_4H_9

Scheme 1

Results and Discussion

Preliminary experiments were carried out on styrene **1a** and diphenyl diselenide **2a** in order to optimize the reaction conditions, in the synthesis of (2-methoxy-2-phenylethyl)(phenyl)selane **3a**, the results are summarized in Table 1. When a mixture of styrene **1a** (0.5 mmol), diphenyl diselenide **2a** (0.25 mmol) and Oxone® (0.125 mmol) in methanol (3.0 mL) was stirred at room temperature for 8.0 h, the desired product **3a** was obtained in 30% yield (Table 1, entry 1). Aiming

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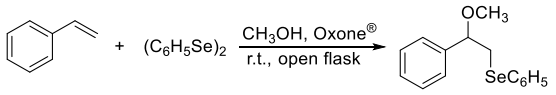
to improve this result, the amount of Oxone® was increased to 0.25 mmol and fortunately, yield increased to 93% in 3.5 h (Table 1, entry 2). A decrease in the yield of **3a** was observed when 0.50 mmol of Oxone® was used, probably due to the oxidation of the *β*-methoxy-selenides under these conditions, as previously reported[15] (Table 1, entry 3). Additionally, if no oxidizing agent is present, no product **3a** is formed, as indicated by GC/MS analysis (Table 1, entry 4). Regarding the influence of the reaction time, it was observed that 3.5 h gave the best result, almost no difference in the yield was observed after 5 hours (Table 1, entries 2 *vs* 5 and 6). A small amount of 1-phenyl-2-(phenylseleno)ethanol **4a** (< 3%), formed by the attack of OH as nucleophile in the seleniranium intermediate, was observed in all the tested reactions. To avoid the formation of side products, the reaction was carried out using dry Oxone® and methanol in a closed flask. However, similar yields, as well as the presence of trace amounts of **4a** were observed (Table 1, entry 7).

Table 1. Optimization of selenomethoxylation of olefins by Oxone®.[a]



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

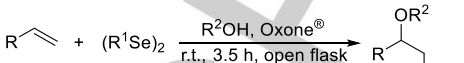
Entry	Oxone® (mmol)	Time (h)	Yield of **3a** (%)[b],[c]
1	0.125	8.0	30
2	0.250	3.5	93
3	0.500	3.5	52
4	-	3.5	nr
5	0.250	2.5	79
6	0.250	5.0	92
7	0.250	3.5	85[d]

[a] Reactions performed using styrene **1a** (0.5 mmol), $(C_6H_5Se)_2$ **2a** (0.25 mmol) and Oxone® in methanol (3.0 mL) in an open flask at room temperature. [b] Isolated yields. [c] Observed the presence of 1-phenyl-2-(phenylseleno)ethanol **4a** in trace amounts (< 3%), determined by CG-MS. [d] Performed using dry Oxone® in a closed flask. nr = no reaction.

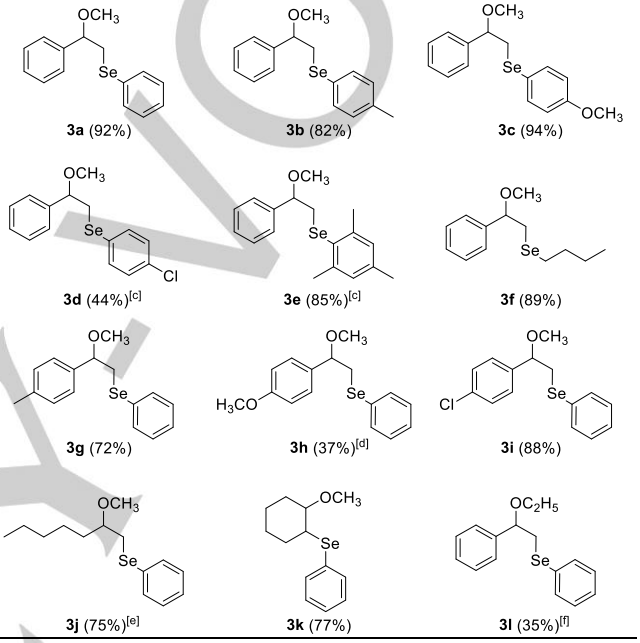
From the results collected in Table 1, the best reaction conditions were defined as the stirring of a mixture of styrene **1a** (0.5 mmol), diphenyl diselenide **2a** (0.25 mmol) and Oxone® (0.25 mmol) in methanol (3.0 mL) for 3.5 h at room temperature (Table 1, entry 2).

Once the best reaction conditions were determined for the synthesis of **3a**, the scope and limitations of the methodology were explored by reacting a variety of alkenes **1a**-**e** with a range of diorganyl diselenides **2a**-**f** (Table 2). The results showed in Table 2 reveal that our protocol is general, working well for most of the employed substrates. The reaction showed to be sensitive to electronic effects in the aryl moiety of the diorganyl diselenides **2a**-**d**. The presence of electron-releasing and electron-neutral substituents in the aromatic ring of the diaryl diselenides **2a**-**c** (R^1 = C_6H_5, 4-$CH_3C_6H_4$ or 4-$CH_3OC_6H_4$) positively influenced the reactivity, compared to the electron-poor diselenide **2d** (R^1 = 4-ClC_6H_4). Further, to obtain compound **3d** in satisfactory yield, a mixture MeOH/THF (2:1) was necessary to homogenizing the mixture and accelerate the reaction. In a similar way, the same mixture of solvents under reflux was used to give a good yield of *β*-methoxy-selenide **3e** (R^1 = mesityl), derived from the sterically hindered dimesityl diselenide **2e**. The performance of the reaction was very good using the aliphatic dibutyl diselenide **2f**, with the product of interest **3f** (R^1 = C_4H_9) being isolated in 89% yield after 3.5 h.

Table 2. Synthesis of *β*-alkoxy-selenides **3a**-**l** promoted by Oxone®.[a],[b]



1 **2** **3**



[a] Reactions performed in the presence of alkene **1a**-**f** (0.5 mmol), diorganyl diselenide **2a**-**f** (0.25 mmol), CH_3OH (3.0 mL), Oxone® (0.25 mmol) under open flask at room temperature for 3.5 h. [b] Isolated yields. [c] CH_3OH/THF (2:1) under reflux for 20 h. [d] Under 50 °C. [e] A 4:1 mixture of isomers (Markovnikov)/(anti-Markovnikov adduct) was isolated. [f] C_2H_5OH (3.0 mL) was used instead CH_3OH.

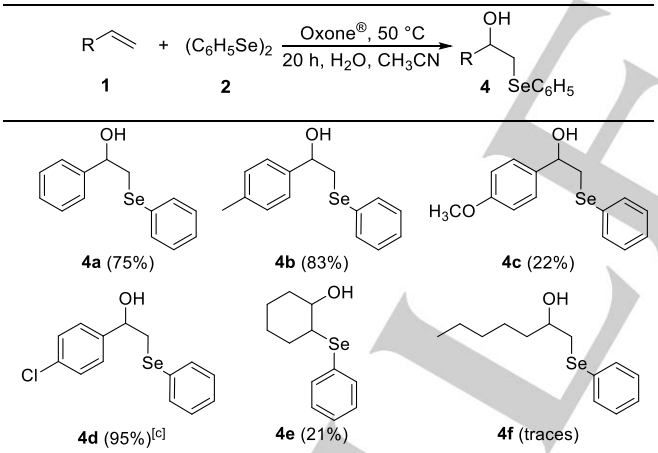
Afterward, the possibility of performing these reactions with different alkenes **1b**-**e** was also investigated. Differently of the observed in the aromatic diselenides, the presence of electron-withdrawing group 4-Cl in the styryl derivative **1d** did not influence negatively the reaction and the desired *β*-methoxy-selenide **3i** (R = 4-ClC_6H_4) was obtained in 88% yield. This outcome is like that observed for neutral **1a** and discreetly electron-rich 4-tolylstyrene **1b**, that afforded the respective *β*-methoxy-selenides **3a** (R = C_6H_5) and **3g** (R = 4-$CH_3C_6H_4$) in 92% and 72% yields, respectively. The presence of the strong electron-donor CH_3O group however, like in 4-methoxystyrene **1c** caused a drastic reduction in the reaction yield, and *β*-methoxy-selenide **3h** (R = 4-$CH_3OC_6H_4$) was obtained in only 37% yield, even if the reaction temperature was increased to 50 °C. This moderate yield could probably be associated with the low solubility of **1c** in the reaction medium. The low reactivity of 4-methoxystyrene in the presence of Oxone® was already observed before, by Parida and Moorthy,[32] during their studies on the cleavage of olefins to

carboxylic acids. A number of unidentified by-products derived from parallel reactions were observed.

Not only styrene derivatives were reactive under our conditions, but also the common alkene hept-1-ene **1e** furnished **3j** (R = C_5H_{11}) as a 4:1 mixture of Markovnikov and anti-Markovnikov adducts in 75% yield. We also examined the reaction of cyclohexene **1f**, affording the respective *β*-methoxy-selenide **3k** [R = -$(CH_2)_4$-] in 77% yield. The reaction performed with ethanol as nucleophile and solvent instead methanol furnished the expected *β*-ethoxy-selenide **3l** (R^2 = C_2H_5) in poor yield (35%) after 3.5 h. Additional reactions were conducted aiming to obtain higher yields of **3l**, however even after 20 h under reflux, the isolated yield was the same.

In order to extend the scope of the present methodology, we attempted to synthesize *β*-hydroxy-selenides by using aqueous medium (Table 3). In a first assay, the reaction of styrene **1a**, diphenyl diselenide **2a** and Oxone® in a 2:1 mixture of H_2O/CH_3CN (3.0 mL) as the solvent, provided 1-phenyl-2-(phenylseleno)ethanol **4a** (R = C_6H_5) in 53% yield after 5 h at room temperature. To our delight, when the temperature was increased to 50 °C, the desired *β*-hydroxy-selenide **4a** was obtained in 75% yield after 20 h. This optimal reaction conditions extended to substituted styrenes **1b**-**d**. Similar to the observed in the selenomethoxylation reactions (Table 2), the presence of a CH_3 group in the aromatic ring (4-tolylstyrene **1b**) did not considerably affect the reaction, and the respective *β*-hydroxy-selenide **4b** (R = 4-$CH_3C_6H_4$) was isolated in 83% yield after 20 h at 50 °C.

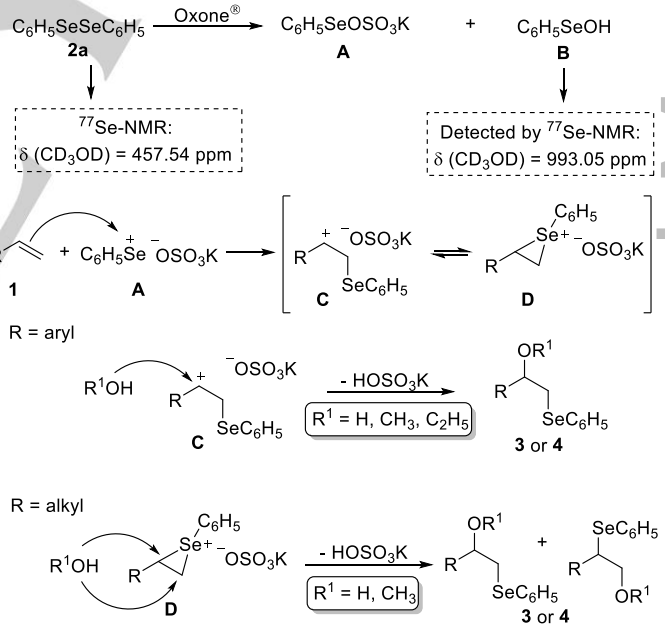
Table 3. Synthesis of *β*-hydroxy-selenides **4a**-**f** promoted by Oxone®.[a],[b]



[a] Reactions performed in the presence of alkene **1a**-**f** (0.5 mmol), diphenyl diselenide **2a** (0.25 mmol), H_2O/CH_3CN (1:2, 3.0 mL), Oxone® (0.25 mmol) under open flask at 50 °C for 20 h. [b] Isolated yields. [c] Under room temperature for 5 h.

The presence of the strongly electron-donating OCH_3 (4-methoxy-styrene **1c**), however, negatively affected the reaction, affording the expected **4c** (R = 4-$CH_3OC_6H_4$) in only 22% yield. The reaction was considerably faster using 4-chloro-styrene **1d**, with *β*-hydroxy-selenide **4d** (R = 4-ClC_6H_4) being obtained in 95% yield at room temperature after only 5 h. The protocol was applied to cyclohexene **1e**, however the desired 2-(phenylselanyl)cyclohexan-1-ol **4e** [R = -$(CH_2)_4$-] was obtained in only 21% yield. Unfortunately, the product of the reaction with hept-1-ene **1f** (R = C_5H_{11}) could not be obtained in isolable amount using our method.

Based on our results and those from the literature,[23,25,33] a plausible mechanism for the selenomethoxylation of styrene **1a** with $(C_6H_5Se)_2$ **2a** promoted by Oxone® in methanol or aqueous medium is proposed in Scheme 2. We believe that Oxone® at first reacts with diphenyl diselenide **2a** to generate intermediates **A** and **B**. ^{77}Se-NMR analysis and MS were used to confirm the formation of these intermediates. When equivalent amounts of **2a** and Oxone® were mixed in a NMR tube (CD_3OD), the reaction started and after few minutes, the signal at 457.54 ppm in the ^{77}Se-NMR spectra, characteristic of starting $(C_6H_5Se)_2$ **2a**, disappeared and the only observed signal was a peak at 993.05 ppm, attributed to intermediate **B**.[34] Intermediate **A** was not noticeable in NMR, but its presence was detected by MS. Once the electrophilic selenium species **A** is formed, it reacts with the carbon-carbon double bond of the alkene **1** to produce the carbocation **C**, which can be stabilized by the organoselenium group, via the seleniranium intermediate **D**. When aryl alkenes were used, the carbocation **C** undergoes a nucleophilic attack by R^1OH (R^1 = CH_3, C_2H_5 or H) to give the respective product **3** or **4**, *via* a S_N1 mechanism.[26] From alkyl alkenes, the formation of seleniranium species **D** is favored, which is nucleophilically opened by R^1OH (R^1 = CH_3 or H) to give a mixture of Markovnikov and anti-Markovnikov adducts **3** or **4**.[26]



Scheme 2

Conclusions

An efficient methodology to prepare *β*-methoxy-selenides and *β*-hydroxy-selenides by selenomethoxylation and selenohydroxylation of alkenes using the Oxone® as a stoichiometric oxidant was developed. The electrophilic species of selenium was generated *in situ* from easily available diorganyl diselenides in the presence of oxidizing agent. The reactions

proceeded at room temperature or gentle heating at 50 °C for few hours, affording the corresponding compounds in moderate to excellent yields. The protocol is versatile and was successfully applied to aromatic and aliphatic diselenides and alkenes.

Experimental Section

The reactions were monitored by thin layer chromatography (TLC) was performed using Merck silica gel (60 F_{254}), 0.25 mm thickness. For visualization, TLC plates were either placed under UV light, or stained with iodine vapor, or and 5% vanillin in 10% H_2SO_4 and heat. Column chromatography was performed using Merck Silica Gel (230-400 mesh). High resolution mass spectra (HRMS) were recorded on a Bruker Micro TOF-QII spectrometer 10416. Low-resolution mass spectra (MS) were measured on a Shimadzu GC-MS-QP2010 mass spectrometer. NMR spectra were recorded with Bruker DPX (^{1}H NMR = 400 and 500 MHz; ^{13}C NMR = 100 and 125 MHz; ^{77}Se NMR = 76 MHz) instruments using, were otherwise indicated, $CDCl_3$ as solvent and calibrated using tetramethylsilane (TMS) for ^{1}H and ^{13}C NMR and $(PhSe)_2$ for ^{77}Se-NMR as internal standard. Coupling constants (*J*) are reported in Hertz and chemical shift (*δ*) in ppm. The reagents (alkenes and Oxone®) were purchased from Sigma-Aldrich.

General Procedure for the Synthesis of *β*-alkoxy-selenides 3a-l: To a 10 mL glass tube containing a mixture of alkene **1** (0.5 mmol) and an appropriate diorganyl diselenide **2** (0.25 mmol) in methanol (3.0 mL), Oxone® (0.25 mmol, 0.077 g) was added. The resulting mixture was stirred for the time indicated in Table 2 at room temperature (r.t.; 25 °C) in open flask. The reactions were monitored by TLC until total disappearance of the starting materials. After that, the reaction mixture was received in water (50.0 mL), extracted with ethyl acetate (3x 15.0 mL), dried over $MgSO_4$ and concentrated under vacuum. The residue was purified by column chromatography on silica gel using hexane as the eluent. All the compounds were properly characterized by MS, ^{1}H NMR and ^{13}C NMR.

(2-Methoxy-2-phenylethyl)(phenyl)selane **3a**: Yield: 0.134 g (92%); yellow oil.[23] ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.45-7.49 (m, 2H), 7.20-7.37 (m, 8H), 3.34 (dd, *J* = 8.4 and 5.0 Hz, 1H), 3.32 (dd, *J* = 12.3 and 8.4 Hz, 1H), 3.24 (s, 3H), 3.10 (dd, *J* = 12.3 and 5.0 Hz, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 140.9, 132.6, 130.6, 129.0, 128.5, 128.1, 126.8, 126.6, 83.2, 57.0, 35.3. MS (rel. int) *m*/*z*: 77 (16.6), 91 (13.0), 121 (100.0), 135 (1.9), 157 (2.3), 292 (6.9).

(2-Methoxy-2-phenylethyl)(4-tolyl)selane **3b**: Yield: 0.125 g (82%); yellow oil. [23] ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.38 (d, *J* = 8.3 Hz, 2H), 7.25-7.36 (m, 5H), 7.05 (d, *J* = 8.3 Hz, 2H), 4.32 (dd, *J* = 8.4 and 5.1 Hz, 1H), 3.28 (dd, *J* = 12.3 and 8.4 Hz, 1H), 3.24 (s, 3H), 3.05 (dd, *J* = 12.3 and 5.1 Hz, 1H), 2.31 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 141.0, 136.9, 133.1, 129.8, 128.5, 128.0, 126.7, 83.1, 57.0, 35.7, 21.0. MS (rel. int) *m*/*z*: 77 (12.6), 91 (16.0), 121 (100.0), 171 (1.7), 306 (8.6).

2-Methoxy-2-phenylethyl(4-methoxyphenyl)selane **3c**: Yield: 0.151 g (94%); yellow oil. [23] ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.44 (d, *J* = 8.9 Hz, 2H), 7.35-7.25 (m, 5H), 6.78 (d, *J* = 8.9 Hz, 2H), 4.29 (dd, *J* = 8.3 and 5.1 Hz, 1H), 3.77 (s, 3H), 3.23 (dd, *J* = 12.3 and 8.3, 1H), 3.23 (s, 3H), 3.00 (dd, *J* = 12.3 and 5.1 Hz, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 159.2, 141.0, 135.5, 128.4, 127.9, 126.6, 120.3, 114.7, 83.1, 56.9, 55.2, 36.3. MS (rel. int) *m*/*z*: 77 (12.7), 91 (10.4), 121 (100.0), 187 (3.9), 322 (13.3).

4-Chlorophenyl(2-methoxy-2-phenylethyl)selane **3d**: Yield: 0.072 g (44%); yellow oil. [23] ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.37 (d, *J* = 8.7 Hz, 2H), 7.27-7.36 (m, 5H), 7.18 (d, *J* = 8.7 Hz, 2H), 4.33 (dd, *J* = 8.3 and 5.1 Hz, 1H), 3.29 (dd, *J* = 12.3 and 8.3 Hz, 1H), 3.23 (s, 3H), 3.07 (dd, *J* = 12.3 and 5.1 Hz, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 140.7, 134.0, 133.0, 129.1, 128.9, 128.5, 128.1, 126.6, 83.1, 57.0, 35.7. MS (rel. int) *m*/*z*: 77 (11.2), 91 (9.1), 121 (100.0), 191 (1.6), 326 (5.0).

Mesityl(2-methoxy-2-phenylethyl)selane **3e**: Yield: 0.142 g (85%); yellow oil. ^{1}H NMR ($CDCl_3$, 500 MHz) *δ* (ppm) = 7.24-7.33 (m, 5H), 6.91 (s, 2H), 4.21 (dd, *J* = 8.8 and 4.7 Hz, 1H), 3.21 (s, 3H), 3.05 (dd, *J* = 12.1 and 8.8 Hz, 1H), 2.79 (dd, *J* = 12.1 and 4.7 Hz, 1H), 2.51 (s, 6H), 2.25 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 143.0, 141.2, 138.0, 128.4, 128.36, 128.1, 128.0, 126.5, 83.4, 56.9, 35.0, 24.4, 20.9. ^{77}Se NMR (76 MHz, $CDCl_3$): δ = 155 ppm. MS (rel. int) *m*/*z*: 77 (9.9), 91 (12.0), 121 (100.0), 135 (12.3), 334 (12.2). HRMS: Calculated mass for $C_{18}H_{22}OSe$ $[M + Na]^+$: 357.0734, found: 357.0747.

Butyl(2-methoxy-2-phenylethyl)selane **3f**: Yield: 0.121 g (89%); yellow oil. [23] ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.26-7.37 (m, 5H), 4.32 (dd, *J* = 7.8 and 5.5 Hz, 1H); 3.24 (s, 3H), 2.97 (dd, *J* = 12.3 and 7.8 Hz, 1H); 2.73 (dd, *J* = 12.3 and 5.5 Hz, 1H); 2.48 (t, *J* = 7.3 Hz, 2H); 1.58 (quint, *J* = 7.3 Hz, 2H); 1.35 (sex, *J* = 7.3, 2H); 0.89 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 141.2, 128.4, 127.9, 126.6, 84.4, 56.8, 32.6, 31.0, 24.5, 22.9, 13.5. MS (rel. int) *m*/*z*: 77 (9.6), 91 (8.7), 121 (100.0), 272 (6.8).

2-Methoxy-2-(4-tolyl)ethyl(phenyl)selane **3g**: Yield: 0.110 g (72%); yellow oil. [23] ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.45-7.49 (m, 2H), 7.13-7.26 (m, 7H), 4.31 (dd, *J* = 8.4 and 5.1 Hz, 1H), 3.32 (dd, *J* = 12.2 and 8.4 Hz, 1H), 3.23 (s, 3H), 3.09 (dd, *J* = 12.2 and 5.1 Hz, 1H), 2.34 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 137.82, 137.8, 132.5, 130.7, 129.2, 129.0, 126.7, 126.6, 82.9, 56.9, 35.3, 21.2. MS (rel. int) *m*/*z*: 77 (3.5), 105 (4.6), 119 (5.0), 135 (100.0), 306 (6.2).

2-Methoxy-2-(4-methoxyphenyl)ethyl(phenyl)selane **3h**: Yield: 0.060 g (37%); yellow oil. ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.44-7.48 (m, 2H), 7.19-7.24 (m, 5H), 6.85-6.89 (m, 2H), 4.30 (dd, *J* = 8.2 and 5.4 Hz, 1H), 3.79 (s, 3H), 3.32 (dd, *J* = 12.2 and 8.2 Hz, 1H), 3.21 (s, 3H), 3.08 (dd, *J* = 12.2 and 5.4 Hz, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 159.4, 132.8, 132.5, 130.7, 128.9, 127.8, 126.7, 113.9, 82.7, 56.7, 55.2, 35.3. ^{77}Se NMR (76 MHz, $CDCl_3$): δ = 275 ppm. MS (rel. int) *m*/*z*: 77 (5.0), 91 (8.8), 119 (4.0), 135 (8.7), 151 (100.0), 322 (2.8). HRMS: Calculated mass for $C_{16}H_{18}O_2Se$ [M]+: 322.0467,

found: 322.0477.

2-(4-Chlorophenyl)-2-methoxyethyl(phenyl)selane **3i**: Yield: 0.143 g (88%); yellow oil.[23] ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.36-7.38 (m, 2H), 7.20-7.23 (m, 2H), 7.13-7.16 (m, 5H), 4.23 (dd, *J* = 7.9, 5.4 Hz, 1H), 3.20 (dd, *J* = 12.4, 7.9 Hz, 1H), 3.14 (s, 3H), 2.97 (dd, *J* = 12.4, 5.4 Hz, 1H). ^{13}C NMR ($CDCl_3$, 125 MHz) *δ* (ppm) = 139.3, 133.7, 132.7, 130.3, 129.0, 128.6, 128.0, 126.9, 82.5, 57.0, 35.1. MS (rel. int) *m*/*z*: 77 (10.3), 91 (23.1), 111 (2.3), 125 (3.8), 155 (100.0), 326 (6.8).

2-Methoxyheptyl(phenyl)selane **3j**: Yield: 0.107 g (75%); yellow oil, (4:1 mixture of regioisomers). Markovnikov adduct ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.42-7.50 (m, 2H), 7.14-7.20 (m, 3H), 3.25 (s, 3H), 3.01 (dd, *J* = 12.2 and 5.5 Hz, 1H), 2.92 (dd, *J* = 12.2 and 6.1 Hz, 1H), 1.42-1.61 (m, 3H), 1.12-1.40 (m, 5H), 0.80 (t, *J* = 7.0 Hz, 3H). ^{77}Se NMR (76 MHz, $CDCl_3$): δ = 257 ppm. MS (rel. int) *m*/*z*: 55 (71.0), 83 (100.0), 115 (86.1), 157 (11.5), 286 (25.6). anti-Markovnikov adduct ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.42-7.50 (m, 2H), 7.14-7.20 (m, 3H), 3.39-3.49 (m, 1 H), 3.27-3.32 (m, 1H), 3.24 (s, 3H), 1.42-1.61 (m, 3H), 1.12-1.40 (m, 5H), 0.80 (t, *J* = 7.0 Hz, 3H). ^{77}Se NMR (76 MHz, $CDCl_3$): δ = 343 ppm. MS (rel. int) *m*/*z*: 55 (100.0), 97 (69.1),129 (9.7), 157 (7.7), 286 (30.3). Regioisomers ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 134.7, 132.6, 130.7, 129.0, 128.9, 127.4, 126.7, 58.6, 56.9, 44.9, 33.8, 32.2, 32.0, 31.8, 31.6, 27.3, 24.9, 22.5, 22.47, 14.0. HRMS: Calculated mass for $C_{15}H_{22}OSe$ [M]+: 286.0831, found: 286.0840.

2-Methoxycyclohexyl(phenyl)selane **3k**: Yield: 0.104 g (77%); colorless oil.[26] ^{1}H NMR ($CDCl_3$, 500 MHz) *δ* (ppm) = 7.57-7.60 (m, 2H), 7.23-7.28 (m, 3H), 3.37 (s, 3H), 3.24-3.29 (m, 1H), 3.15-3.19 (m, 1H), 2.12-2.16 (m, 1H), 1.97-2.03 (m, 1H), 1.67-1.74 (m, 1H), 1.57-1.62 (m, 1H), 1.45-1.53 (m, 1H), 1.21-1.36 (m, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz) *δ* (ppm) = 135.2, 128.9, 128.7, 127.3, 82.1, 56.3, 47.3, 32.1, 30.2, 25.7, 23.4. MS (rel. int) *m*/*z*: 77 (5.2), 81 (100.0), 113 (33.1), 157 (3.1), 270 (14.4).

2-Ethoxy-2-phenylethyl(phenyl)selane **3l**: Yield: 0.054 g (35%); colorless oil.[26] ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.46-7.49 (m, 2H), 7.20-7.35 (m, 8H), 4.46 (dd, *J* = 8.4 and 5.1 Hz, 1H), 3.30-3.43 (m, 3H), 3.09 (dd, *J* = 12.2 and 5.1 Hz, 1H), 1.17 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 141.7, 132.6, 130.9, 128.9, 128.5, 127.9, 126.7, 126.6, 81.4, 64.7, 35.6, 15.2. MS (rel. int) m/z: 77 (14.7), 107 (59.7), 135 (100.0), 157 (3.8), 306 (6.4).

General Procedure for the Synthesis of *β*-hydroxy-selenides 4a-e: To a 10 mL glass tube containing a mixture of alkene **1** (0.5 mmol) and an appropriate diorganyl diselenide **2** (0.25 mmol) in H_2O/CH_3CN (1:2, 3.0 mL), Oxone® (0.25 mmol, 0.077 g) was added. The resulting mixture was stirred for the time indicated in Table 2 at room temperature (r.t.; 25 °C) in open flask. After that, the reaction mixture was received in water (50.0 mL), extracted with ethyl acetate (3x 15.0 mL), dried over $MgSO_4$, and concentrated under vacuum. The residue was purified by column chromatography on silica gel using hexane as the eluent. All the compounds were properly characterized by MS, ^{1}H NMR and ^{13}C NMR.

1-Phenyl-2-(phenylseleno)ethanol **4a**: Yield: 0.104 g (75%); yellow oil. [27] ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.42-7.44 (m, 2H), 7.22-7.23 (m, 4H), 7.15-7.20 (m, 4H), 4.64 (dd, *J* = 9.4 and 3.7 Hz, 1H), 3.18 (dd, *J* = 12.8 and 3.7 Hz, 1H), 3.01 (dd, *J* = 12.8 and 9.4 Hz, 1H), 2.84 (brs, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 142.4, 133.1, 129.2, 129.1, 128.5, 127.9, 127.4, 125.8, 72.2, 38.4. MS (rel. int) m/z: 77 (58.4), 91 (45.2), 107 (58.9), 157 (16.6), 172 (100.0), 278 (33.0).

1-(4-Tolyl)-2-(phenylseleno)ethanol **4b**: Yield: 0.121 g (83%); yellow oil.[23] ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.50-7.53 (m, 2H), 7.20-7.25 (m, 5H), 7.11-7.13 (m, 2H), 4.71 (dd, *J* = 9.2 and 4.0 Hz, 1H), 3.26 (dd, *J* = 12.7 and 4.0 Hz, 1H), 3.13 (dd, *J* = 12.7 and 9.2 Hz, 1H), 2.75 (brs, 1H), 2.32 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 139.6, 137.6, 133.0, 129.3, 129.15, 129.1, 127.2, 125.7, 72.1, 38.3, 21.1. MS (rel. int) m/z: 77 (59.3), 91 (100.0), 115 (36.0), 157 (11.1), 172 (80.5), 292 (13.5).

1-(4-Methoxyphenyl)-2-(phenylseleno)ethanol **4c**: Yield: 0.034 g (22%); yellow oil. ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.50-7.53 (m, 2H), 7.23-7.26 (m, 5H), 6.84-6.86 (m, 2H), 4.71 (dd, *J* = 9.1 and 4.1 Hz, 1H), 3.78 (s, 3H), 3.26 (dd, *J* = 12.7 and 4.1 Hz, 1H), 3.14 (dd, *J* = 12.7 and 9.1 Hz, 1H), 2.75 (brs, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 159.3, 134.7, 133.0, 129.3, 129.2, 127.2, 127.0, 113.9, 72.0, 55.2, 38.3. ^{77}Se NMR (76 MHz, $CDCl_3$): δ = 250 ppm. MS (rel. int) m/z: 77 (56.1), 91 (46.9), 137 (100.0), 172 (66.1), 210 (26.5), 308 (6.6). HRMS: Calculated mass for $C_{15}H_{16}O_2Se$ [M]+: 308.0311, found: 308.0321.

1-(4-Chlorophenyl)-2-(phenylseleno)ethanol **4d**: Yield: 0.148 g (95%); yellow oil.[27] ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.48-7.51 (m, 2H), 7.20-7.27 (m, 7H), 4.68 (dd, *J* = 9.1 and 4.0 Hz, 1H), 3.22 (dd, *J* = 12.8 and 4.0 Hz, 1H), 3.06 (dd, *J* = 12.8 and 9.1 Hz, 1H) 2.93 (brs, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 140.9, 133.5, 133.1, 129.2, 128.9, 128.5, 127.4, 127.1, 71.5, 38.2. MS (rel. int) m/z: 77 (85.0), 91 (55.8), 113 (25.4), 157 (17.5), 172 (100.0), 312 (27.8).

2-(Phenylselanyl)cyclohexanol **4e**: Yield: 0.027 g (21%); yellow oil.[27] ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* (ppm) = 7.58-7.61 (m, 2H), 7.26-7.34 (m, 3H), 3.33 (ddd, *J* = 10.0, 10.0 and 4.2 Hz, 1H), 2.90 (ddd, *J* = 11.2, 10.0 and 3.9 Hz, 1H), 2.11-2.22 (m, 2H), 1.71-1.75 (m, 1H), 1.60-1.66 (m, 1H), 1.16-1.48 (m, 5H). ^{13}C NMR ($CDCl_3$, 100 MHz) *δ* (ppm) = 136.1, 129.0, 128.1, 126.7, 72.3, 53.6, 33.9, 33.4, 26.9, 24.5. MS (rel. int) m/z: 77 (23.3), 81 (100.0), 99 (14.3), 156 (42.7), 256 (35.6).

Mechanism experiments

Procedure to Prepare Intermediate A: To a 10 mL glass tube containing diphenyl diselenide **2a** (0.25 mmol) in methanol (3.0 mL), Oxone® was added. The resulting mixture was stirred for 1 h at room temperature in the open flask. The diphenyl diselenide oxidative cleavage was accompanied by a change in the reaction's solution color, from yellow to white, and the formation of a precipitate. The solvent was separated from the precipitate by decantation and removed with a Pasteur pipette. The resulting solid was dried under vacuum and characterized by MS.

Procedure to Prepare Intermediate B: To a NMR tube containing styrene **1a** and diphenyl diselenide **2a** (0.25 mmol) in methanol (3.0 mL), Oxone® was added. The resulting mixture was used to collect the ^{77}Se NMR data.

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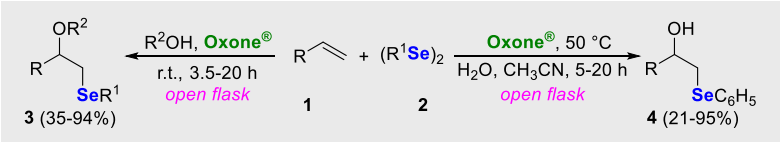

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Selenomethoxylation of Alkenes Promoted by Oxone®

We describe herein an alternative method for the selenomethoxylation of unactivated alkenes using Oxone® as a stoichiometric oxidant. By this efficient and simple approach, *β*-methoxy-selenides were obtained in moderate to excellent yields in an open flask, starting from alkenes and using methanol as both nucleophile and solvent. When a mixture of H_2O/CH_3CN was the solvent, *β*-hydroxy-selenides were selectively obtained under mild conditions.