Chem Rev Lett 7 (2024) 532-544

Research Article

Chemical Review and Letters
journal homepage: www.chemrevlett.com
ISSN (online): 2645-4947 (print) 2676-7279

Direct hydroxyselenenylation of alkenes: A convenient access to β-hydroxy selenides

Esmail Vessally[1,2,] *, Rovnag Rzayev[2]

[1]*Department of Chemistry, Payame Noor University, P.O. Box 19395-3697 Tehran, Iran*
[2]*Composite Materials Scientific Research Center of Azerbaijan State University of Economics (UNEC), 194 M.Mukhtarov str. Baku, Azerbaijan*

ARTICLE INFO

Article history:
Received 16 July 2024
Received in revised form 1 September 2024
Accepted 2 September 2024
Available online 10 September 2024

Keywords:
β-Hydroxy selenides, alkenes, vicinal difunctionalization, hydroxyselenenylation, selenenylating agents.

ABSTRACT

The aim of the present review is to summarize the recent advances in the synthesis of β-hydroxy selenides through the direct hydroxyselenenylation of substituted alkenes in the past 45 years. Hopefully, it can provide practical guidance for the readers who are interested in the application of bifunctionalization reactions in the synthesis of functionalizaed organoselenium compounds. For simplicity and clarity, the organization of this review is based on the type of catalysts.

1. Introduction

Organoselenium compounds are a class of important molecules with an array of biological activities such as antitumor, anti-inflammatory, antioxidant, antifungal, antiviral, among other activities [1]. They also play significant roles in the fields of organic synthesis [2], agrochemicals [3], and *materials science [4]*. Among organoselenium compounds, β-hydroxy selenides have recently attracted tremendous attention owing to their potential biological activities [5] and wide variety of applications in organic synthesis [6, 7]. Traditionally, their synthesis has been achieved ring opening reaction of epoxides with selenium nucleophiles [8]. However, not only some epoxides are toxic and unstable, but also their *production* requires additional steps that can be expensive and environmentally damaging on a large scale. Therefore, development of *efficient* and environmentally benign methodologies for synthesis of β-hydroxy selenother derivatives with high atom- and step-economy in a one-pot manner is *highly desirable*.

Direct difunctionalization of alkenes, the simultaneous incorporation of two functional into the π system, is a *sustainable and versatile* strategy for the rapid assembly of complex molecules from simple and readily available starting materials [9]. In the particular case of difunctionalization reactions, *several* methodologies based on selenative difunctionalization of simple alkenes have been *recently developed* for accessing various organoselenium compounds [10]. In this context, vicinal hydroxyselenenylation of alkenes has emerged as an efficient synthetic strategy for preparing β-hydroxy selenides from readily available starting materials within a single click (Figure 1). To the best of our knowledge, no review of literature reports on the direct hydroxyselenenylation of alkenes has been published to date. This review outlines the major discoveries and developments focusing on the hydroxyselenenylation reactions of alkenes from 1979-2024. According to the type of catalysts, the review divided into seven major sections: (i) electro-catalyzed reactions; (ii) light-induced reactions; (iii) metal-catalyzed reactions; (iv) halogen-catalyzed/mediated reactions; (v) oxidant-mediated reactions; (vi)

* Corresponding author; e-mail: vessally@pnu.ac.ir
https://doi.org/10.22034/crl.2024.468165.1382

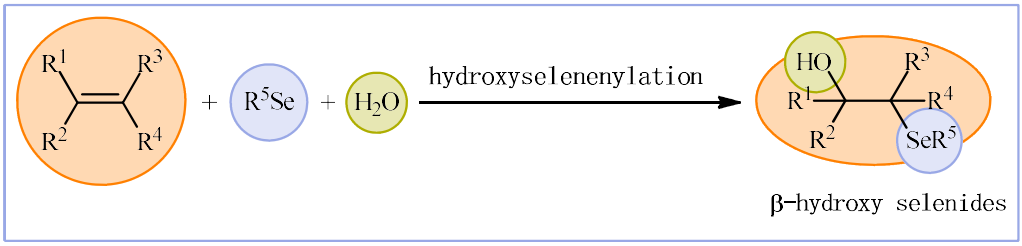
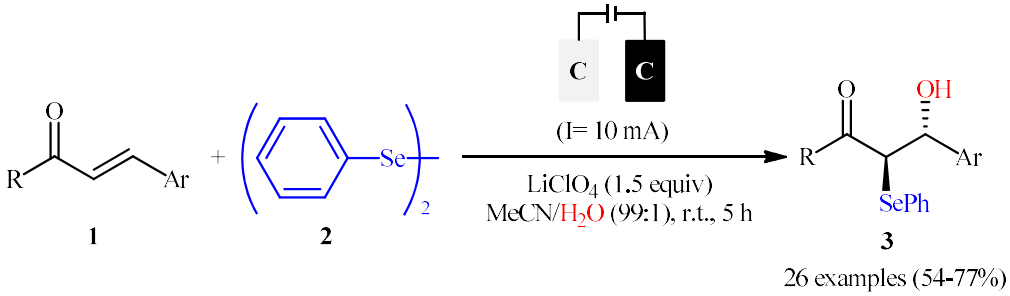


Fig. 1. Direct hydroxyselenenylation of alkenes.

acid/base-catalyzed/mediated reactions; (vii) catalyst-free reactions.

2. Electro-catalyzed reactions

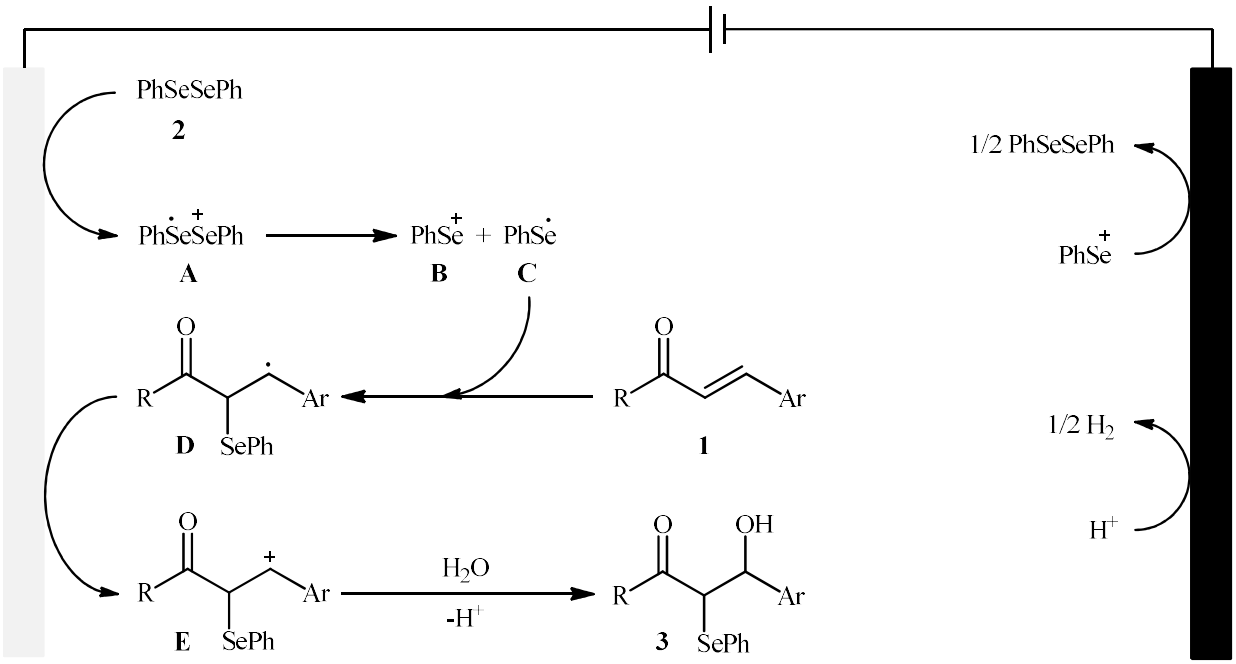
One of the first general reports of the synthesis of β-hydroxy selenides through the regioselective hydroxyselenenylation of alkenes under electrochemical conditions was published in 2024 by Fatma and Khan [11]. In this investigation, twenty-six β-hydroxy selanylated ketones **3** were efficiently synthesized through the treatment of respective α,β-unsaturated ketones **1** with diphenyl diselenide **2** in a single-compartment (undivided) cell with carbon (C) electrodes under constant current of 10 mA at room temperature. The reactions were run in MeCN/H_2O using $LiClO_4$ as supporting electrolyte under an atmosphere of air, tolerated multiple groups of substituents (*e.g.*, OMe, F, Cl, Br, I, NO_2), and provided the expected products **3** in moderate to high yields and outstanding regioselectivities, in which SePh group predominantly added to the carbon atom adjacent to the carbonyl group and OH group placed on the carbon atom near the aryl group (Scheme 1). Notably, both aliphatic and aromatic α,β-unsaturated ketones were compatible substrates in this transformation. The results indicated that generally aromatic ketones afforded better yields compared to aliphatic ketones. On the other hand, aromatic ketones possessing electron-withdrawing groups provided better yields compared to the electron-donating groups present on either of the phenyl ring. Based on a series of control experiments and previous literature backgrounds, the author proposed a plausible mechanistic course for this hydroxyselenenylation, which is shown in Scheme 2. Initially, oxidation of diphenyl diselenide **2** at the anode surface affords radical cation intermediate **A**, which cleavages into phenyl selenium radical **B** and phenyl selenium cation **C**. Next, radical **B** attacks at α-position of ketone **1** to yield carbon-centered radical **D** which after anodic oxidation converts to cationic intermediate **E**. Finally, nucleophilic attack of water on to the benzylic cation **E** affords the final product **3**.



R= Me, Ph, 4-Ph-C_6H_4, 4-F-C_6H_4, 4-Cl-C_6H_4, 4-Br-C_6H_4, 4-I-C_6H_4, 4-NO_2-C_6H_4, 3-Cl-C_6H_4, 2-OMe-C_6H_4, 3,4-$(Cl)_2$-C_6H_4, 2-naphthyl, 3-thienyl

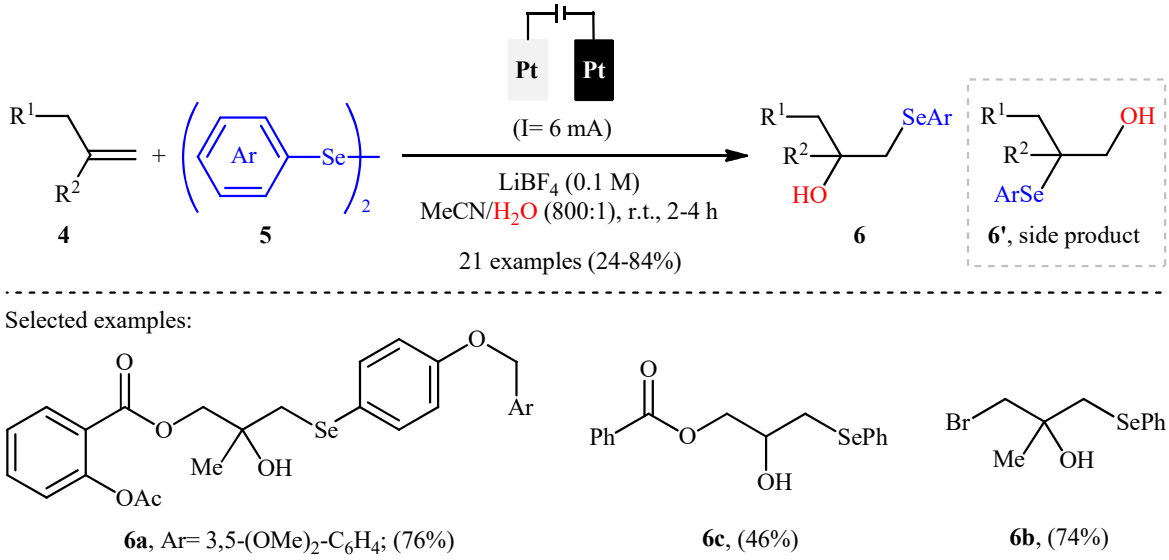
Ar= Ph, 4-Me-C_6H_4, 4-Et-C_6H_4, 4-OMe-C_6H_4, 4-F-C_6H_4, 4-Cl-C_6H_4, 4-Br-C_6H_4, 4-I-C_6H_4, 4-NO_2-C_6H_4, 2-Me-C_6H_4, 2-F-C_6H_4, 2,4-$(Cl)_2$-C_6H_3, 1-naphthyl

Scheme 1. Khan's synthesis of β-hydroxy selenides **3**.



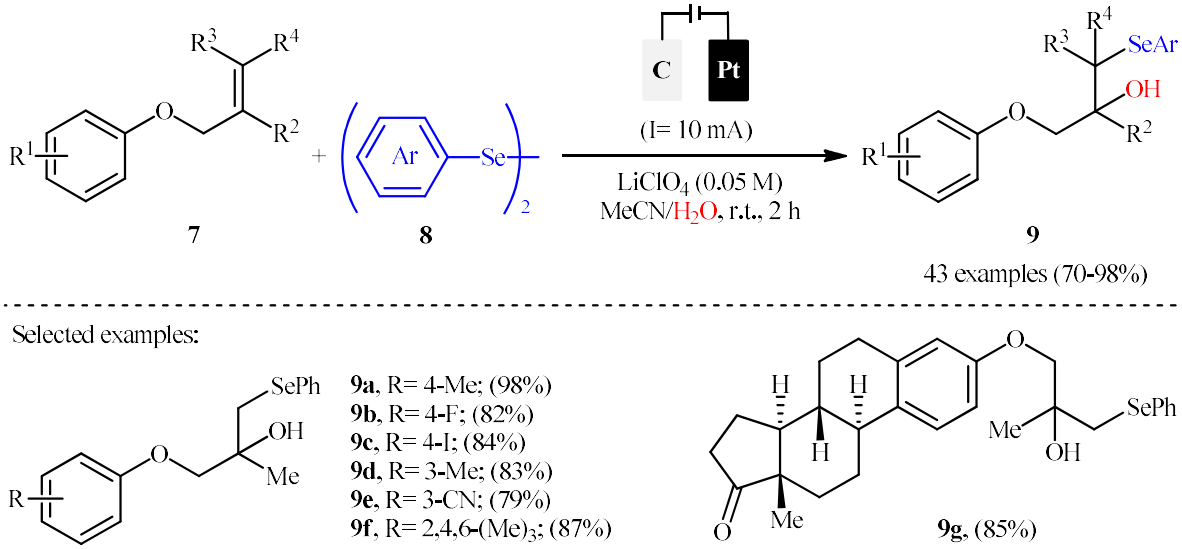
Scheme 2. Plausible mechanism for the formation of β-hydroxy selenides **3**.

Concurrently, Liu and co-workers developed an interesting electrochemical approach for hydroxyselenenylation of terminal alkenes **4** with various biaryl diselenides **5** and water under ambient conditions [12]. The authors identified $LiBF_4$ as the optimal supporting electrolyte, and MeCN as the ideal solvent. The established hydroxyselenenylation reaction was conducted in an undivided Pt/Pt-cell under constant current conditions (6 mA), tolerated both mono- and 1,1-disubstituted alkenes **4**, and provided the corresponding β-hydroxy selenides **6** in poor to high yields (Scheme 3). However, the regioselectivity of reaction was moderate and in most cases mixtures of both Markovnikov and anti-Markovnikov addition to yield optical (RS) isomers were obtained. Unfortunately, dialkyl diselenides were incompatible substrates in this difunctionalization reaction. Furthermore, the use of diphenyldisulfide (PhSSPh) and diphenyl ditelluride (PhTeTePh) were not effective and no desired product were found.



Scheme 3. Liu's synthesis of β-hydroxy selenides **6**.

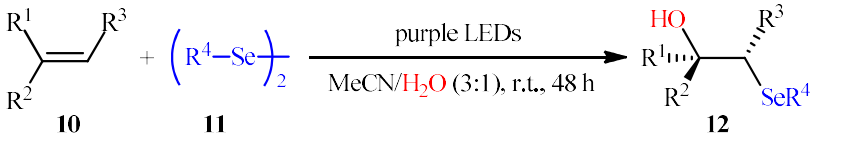
At the same year, Dapkekar and Satyanarayana developed a robust electrochemical hydroxyselenenylation of (allyloxy)arenes **7** using diaryl diselenides **8** and water as the SeAr and OH sources, respectively, for the synthesis of 1-aryloxy-3-(arylselanyl)propan-2-ol derivatives **9** [13]. In an undivided cell assembled with a graphite anode and platinum cathode, the best reaction conditions were achieved with $LiClO_4$ as the electrolyte and acetonitrile as the solvent, with a constant current of 10 mA under air atmosphere at room temperature (Scheme 4). The reaction was tested on 40 different alkene substrates and was able to tolerate a wide range of sensitive functional groups. However, the reaction, appears to be limited to electron-rich diaryl diselenides. Regrettably, the reactions of (allyloxy)heteroarenes were unsuccessful in generating expected β-hydroxy selenides.



Scheme 4. Satyanarayana's synthesis of β-hydroxy selenides **9**.

3. Light-induced reactions

Drawing inspiration from Liu-Ling's work on visible-light-induced oxidative coupling of vinylarenes with diselenides [14], in 2022, Oh and colleagues investigated the possibility of synthesizing β-hydroxy selenides by visible-light-induced hydroxyselenenylation of alkenes [15]. By employing 1-methyl-4-vinylbenzene and diphenyl diselenide as the model substrates, various light sources (*e.g.*, white LEDs, blue LEDs, green LEDs, purple LEDs) and solvent systems (*e.g.*, MeCN/H_2O, THF/H_2O, Me_2CO/H_2O, MeCN, H_2O) were attentively screened. The results showed that the purple LEDs were most suitable light source and a 3:1 mixture of MeCN and H_2O was found to be the most suitable solvent. Under the optimized conditions, a library of 27 β-hydroxy selenides **12** were selectively in yields ranging from 27% to 83% by reaction of various aliphatic and aromatic alkenes **10** with di(aryl/alkyl) diselenides **11** under an atmosphere of air at room temperature (Scheme 5). An α,β-unsaturated carbonyl compound was also tested and gave the desired product but in poor yield (10%). However, the system was not amenable to the hydroxysulfenylation of alkenes using disulfides. Overall the relative reaction rates of alkenes in this methodology followed the order: electron-rich styrene derivative > electron-poor styrene derivatives ≥ aliphatic alkenes > strongly electron-poor styrene derivatives >> α,β-unsaturated carbonyl compounds. On the other hand, diaryl diselenides (either electron-rich or electron-poor) appeared to afford higher yield than dialkyl diselenides under this condition. According to the authors proposed mechanism, this reaction probably proceeds through a selenonium intermediate **D** (Scheme 6).



R^1= Ph, 4-Me-C_6H_4, 4-^{t}Bu-C_6H_4, 4-Ph-C_6H_4, 4-OMe-C_6H_4, 4-F-C_6H_4, 4-Cl-C_6H_4, 4-Br-C_6H_4, 4-CO_2Me-C_6H_4, 4-CF_3-C_6H_4, 4-CN-C_6H_4, 3-Me-C_6H_4, 2-Me-C_6H_4, 2-naphthyl, CH_2Bn, ^{n}Pent

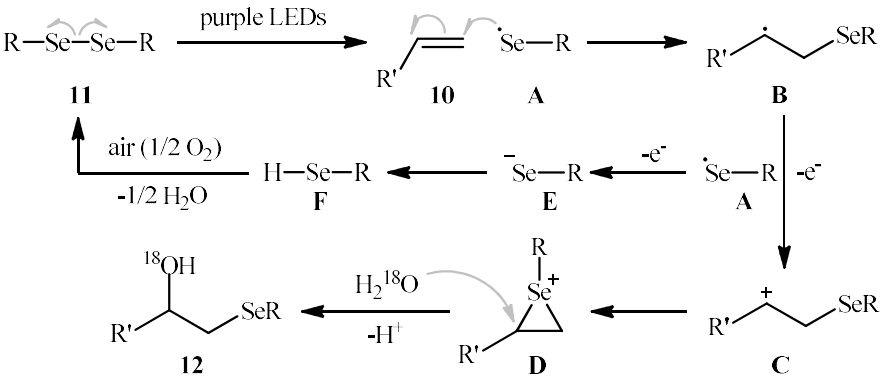
R^2= H, Me

R^3= H, Me

$R^1 + R^3$= 

R^4= Me, Ph, 4-Me-C_6H_4, 4-^{t}Bu-C_6H_4, 4-OMe-C_6H_4, 4-F-C_6H_4, 4-Cl-C_6H_4, 4-Br-C_6H_4, 4-CF_3-C_6H_4

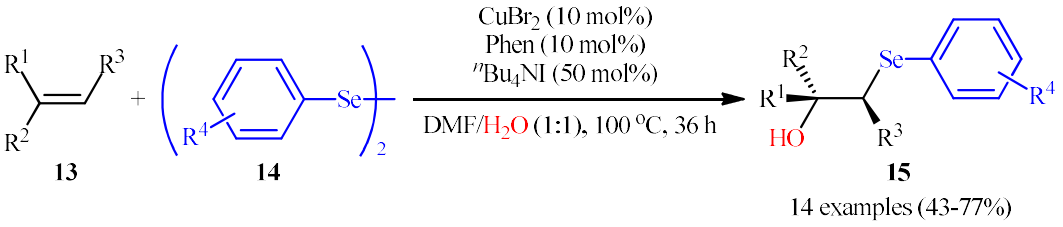
Scheme 5. Oh's synthesis of β-hydroxy selenides **12**.

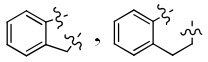


Scheme 6. Proposed mechanism for the formation of β-hydroxy selenides **12**.

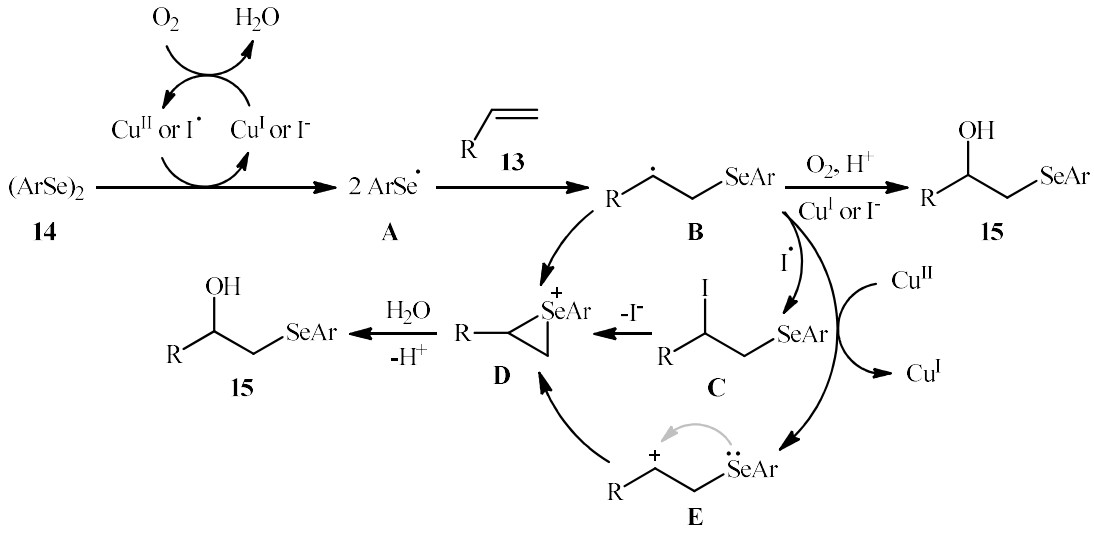
4. Metal-catalyzed reactions

Drawing inspiration from Movassagh's work on Zn/$AlCl_3$-promoted one-pot synthesis of β-hydroxy selenides through the three-component reaction between alkenes, diselenides, and water [16], in 2022, Taniguchi studied the possibility of synthesizing β-hydroxy selenide derivatives *via* transition-metal-catalyzed hydroxyselenenylation of simple alkenes using diselenides under aqueous conditions [17]. Thus, in the presence of $CuBr_2$/Phen/^{n}Bu_4NI combination as a catalytic system in DMF/H_2O (1:1) under air atmosphere, hydroxysulfenylation of styrene derivatives **13** with various diaryl diselenides **14** furnished the corresponding β-hydroxy selenides **15** in modestly to high yields (Scheme 7). However, both aliphatic alkenes and dialkyl diselenides failed to participate in this reaction. Notably, by replacing diaryl diselenides with diaryl disulfides, β-hydroxy sulfides were obtained in high yields under the identical conditions (22 examples, up to 89%). Based on a series of control experiments, a plausible mechanism was suggested for the formation of β-hydroxy selenides **15**, as represented in Scheme 8. It consists of the following key steps: (1) initial formation of the selenyl radical **A** *from diselenide **14** by the oxidation of Cu(II) or in situ generated iodide radical*; (2) regioselective attack of radical **A** to the double bond of alkene **13** to afford alkyl radical **B**; (3) reaction of the newly formed radical **B** with iodide radical to give iodoalkane **C**; (4) elimination of iodide anion from **C** to give selenonium cation **D**; and (5) nucleophilic attack of water onto the intermediate **D** to produce expected β-hydroxy selenide **15**. In another possibility, the observed products might be formed *via* addition of O_2 to alkyl radical **B** through a radical process.



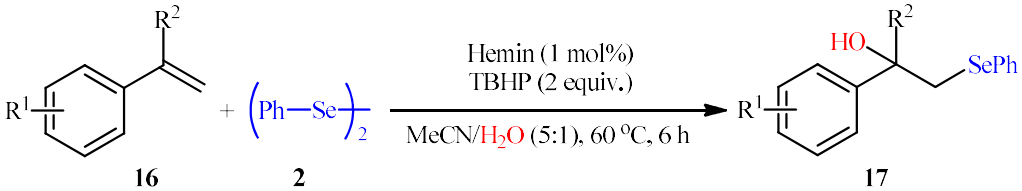
R^1= Ph, 4-Me-C_6H_4, 4-^{t}Bu-C_6H_4M 4-OMe-C_6H_4, 4-F-C_6H_4, 4-Cl-C_6H_4, 2-naphthyl
R^2= H, Me
R^3= H, Me
$R^1 + R^3$= 
R^4= H, 4-Me, 4-OMe, 2,3-(CH=CH)$_2$-

Scheme 7. Taniguchi's synthesis of β-hydroxy selenides **15**.



Scheme 8. Proposed pathway for the formation of β-hydroxy selenides **15**.

Subsequently, Wang and co-workers disclosed that the merge of hemin (an iron porphyrin complex with TBHP (*tert*-butyl hydroperoxide) can be used as effective catalytic system for hydroxyselenenylation of styrenes **16** with diphenyl diselenide **2** in aqueous MeCN (Scheme 9) [18]. Unfortunately, applicability of aliphatic alkenes and the scope and limitation of diselenides were not investigated in this study. Concurrently, Kuang *et al*. unraveled that the combination of Ca(NTf2)$_2$ (5 mol%) and ^{n}Bu$_4$NPF$_6$ (5 mol%) could serve as an efficient catalytic system for hydroxyselenenylation of styrenes using *N*-(phenylseleno)phthalimide as selenation agent [19]. However, only a single example was reported in this investigation.

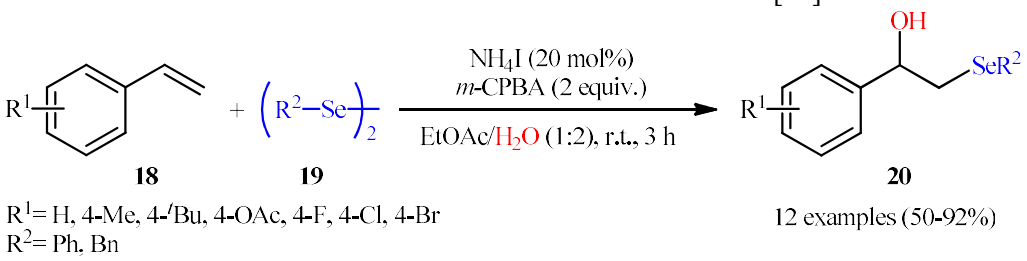


R^1= H, 4-Cl, 3-Cl, 2-Cl
R^2= H, Me

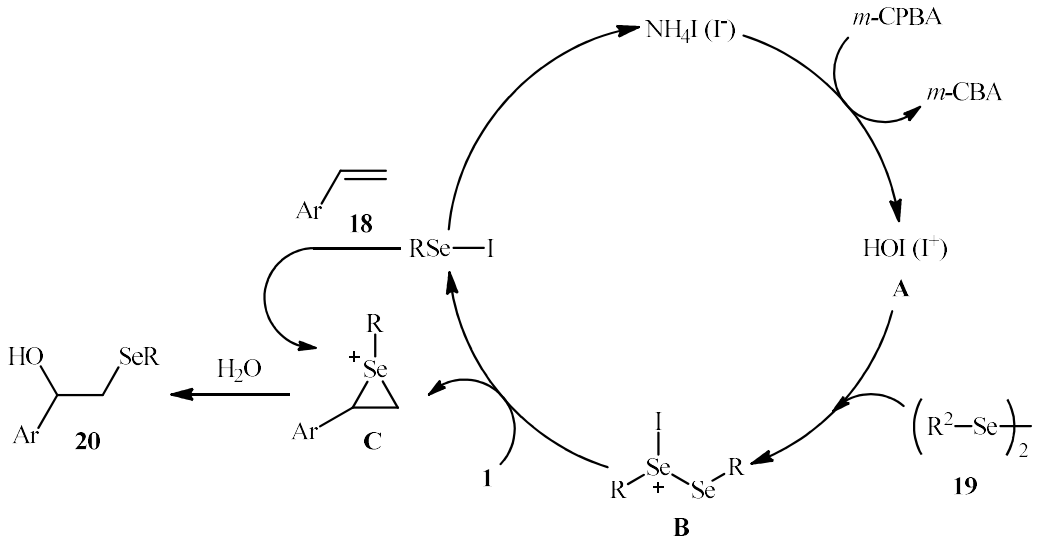
Scheme 9. Wang's synthesis of β-hydroxy selenides **17**.

5. Halogen-catalyzed/mediated reactions

In 2016, Yan co-workers found that the treatment of styrene derivatives **18** with diselenides **19** in the presence of NH_4I/*m*-CPBA combination as a catalytic system in a binary solvent EtOAc/H_2O under ambient conditions afforded the corresponding β-hydroxy selenides **20** in moderate to high yields with excellent regio- and stereo-selectivity (Scheme 10), in which all the obtained products were *trans* stereoisomers with Markovnikov orientation [20]. Moreover, a tolerance for aliphatic alkenes was also demonstrated by using cyclohexene as the substrate. Unfortunately, the applicability of *ortho*- and *meta*-substituted styrenes was not investigated in this study. The plausible mechanism for this reaction is outlined in Scheme 11. At the beginning of the reaction, *m*-CPBA oxidize NH_4I to the corresponding hypoiodous acid **A**. Next, reaction of this intermediate with diselenide **19** affords the active intermediate **B**, which then reacts with alkene **18** to form the selenonium intermediate **C**. Finally, nucleophilic addition of H_2O to the cation **D** provides the target product **20**. In the cycle, the in situ formed aryl hypoiodoselenoite (ArSeI) can further transfer a second equivalent of electrophilic Se to alkene. Two years later, the same research team disclosed that molecular iodine (I_2) could also be effectively promoted this hydroxyfunctionalization reaction without the assistance of additives and terminal oxidants under ambient conditions [21].



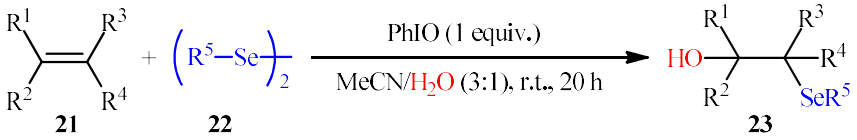
Scheme 10. Yan's synthesis of β-hydroxy selenides **20**.



Scheme 11. Mechanism that accounts for the formation of β-hydroxy selenides **20**.

Along this line, in 2021, Liu and Ling along with their co-workers reported that in the presence of stoichiometric amounts of commercially available hypervalent iodine(III) reagent, PhIO, a diverse range of simple alkenes **21** (terminal, 1,1-disubstituted, 1,2-disubstituted, 1,2,2-tri-substituted, 1,1,2,2,-tetra-substituted alkenes) underwent hydroxyselenation with various di(alkyl/benzyl/aryl/heteroaryl) diselenides **22** in a mixture of water and acetonitrile to produce the corresponding β-hydroxy selenides **23** with yields up to 96% (Scheme 12) [22]. The protocol was also applied to the "late-stage hydroxyselenation" of a series of natural product derivatives and pharmaceutical intermediates such as L-menthol, galactose,

formononetin, vanillylacetone, estrone, naproxen, and tocopherol derivatives. Noteworthy, other nucleophiles such as phenols, carboxylic acids, and amines were also successfully examined in this PhIO-mediated reaction. In the same year, Wang and colleagues unraveled that *N*-fluorobenzenesulfonimide (NFSI) can also efficiently promote hydroxyselenation of internal alkenes with diselenides and water using 1,4-dioxanr as the solvent under ambient conditions [23]. However, terminal alkenes were inert in this protocol.

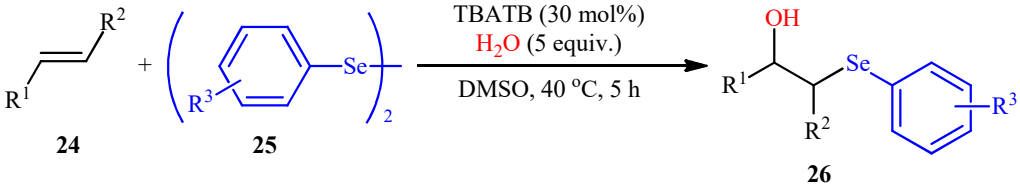


R^1= alky, aryl, heteroaryl
R^2= H, alkyl, aryl
R^3= H, alkyl, aryl
R^4= H, alkyl
R^5= Me, Et, ^{n}Bu, ^{c}Hex, Bn, Ph, 4-^{t}Bu-C_6H_4, 4-OMe-C_6H_4, 3,4-OCH_2O-C_6H_3, 2-naphthyl, 2-thienyl

43 examples (55-96%)

Scheme 12. Liu-Ling's synthesis of β-hydroxy selenides **23**.

Following these works, recently, Wei and co-workers were able to demonstrate that a range of β-hydroxy selenides **26** could be obtained in good to almost quantitative yields (31 examples, 63-98%) from the three-component reaction of alkenes **24** (terminal and internal), diaryl diselenides **25** and water employing tetrabutylammonium tribromide (TBATB) as catalyst in DMSO at 40 °C (Scheme 13) [24]. Additionally, a structurally complex estrone-derived was also successfully reacted with diphenyl diselenide under the identical conditions, affording corresponding β-hydroxy selenide in excellent isolated yield of 93%. Using the same scenario, this research group was able to synthesis a panel of 33 β-hydroxy sulfides in moderate to excellent yields (48-97%) through hydroxysulfurization of respective alkenes with thiols and water.



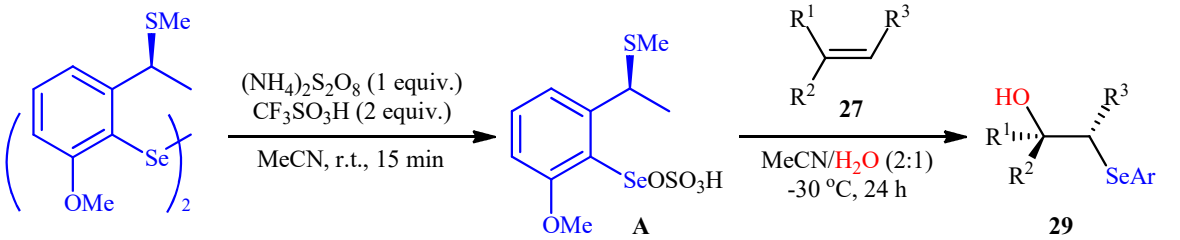
31 examples (63-98%)

R^1= Ph, 4-Me-C_6H_4, 4-^{t}Bu-C_6H_4, 4-Ph-C_6H_4, 4-OMe-C_6H_4, 4-F-C_6H_4, 4-Cl-C_6H_4, 4-Br-C_6H_4, 4-OCOMe-C_6H_4, 4-CO_2Me-C_6H_4, 4-NO_2-C_6H_4, 4-CF_3-C_6H_4, 3-Me-C_6H_4, 3-F-C_6H_4, 3-Cl-C_6H_4, 3-Br-C_6H_4, 3-CF_3-C_6H_4, 2-Me-C_6H_4, 2-naphthyl, CH_2Bn, ^{c}Hex
R^2= H
$R^1 + R^2$= -$(CH_2)_4$-
R^3= H, 4-Me, 4-^{t}Bu, 4-OMe, 4-Cl, 4-CN, 3-Me, 3-OMe, 2-Me, 2,3-$(CH{=}CH)_2$-

Scheme 13. Wei's synthesis of β-hydroxy selenides **26**.

6. Oxidant-mediated reactions

In 2002, Tiecco and co-workers developed an interesting ammonium persulfate [$(NH_4)_2S_2O_8$]-mediated regioselective hydroxyselenenylation of simple alkenes **27** employing their chiral sulfur-containing diselenide **28** as the selenyl source and water as the hydroxyl source (Scheme 14) [25]. Optimal reaction conditions were found to be pre-treating of the diselenide substrate **29** with 1.0 equiv. of $(NH_4)_2S_2O_8$ and 2 equiv. of trifluoromethanesulfonic acid (CF_3SO_3H) in MeCN at room temperature for 15 min. Then the reaction was followed by addition of a solution of alkene **27** in MeCN/H_2O (2:1) and stirring of the resultant mixture at -30 °C for 24 h to complete the hydroxyselenenylation reaction. According to the authors, this reaction was promoted by the $ArSeOSO_3H$ (**A**) generated *in situ* from diselenide and $(NH_4)_2S_2O_8$.

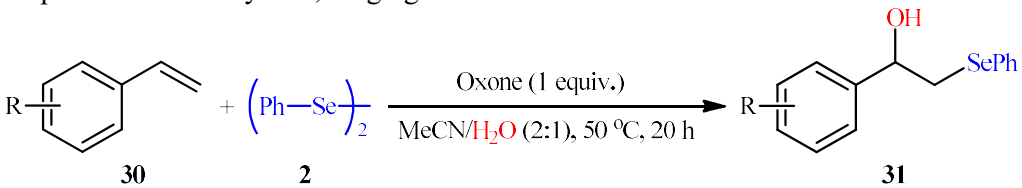


R^1= Ph, 2,4,6-$(Me)_3$-C_6H_2, ^{n}Bu
R^2= H, Me
R^3= H, Me, ^{n}Bu
$R^1 + R^3$= -$(CH_2)_4$-

Scheme 14. Tiecco's synthesis of β-hydroxy selenides **29**.

A similar principle was also successfully applied to the hydroxyselenenylation of simple styrene with a nitrogen containing chiral diselenide [26].

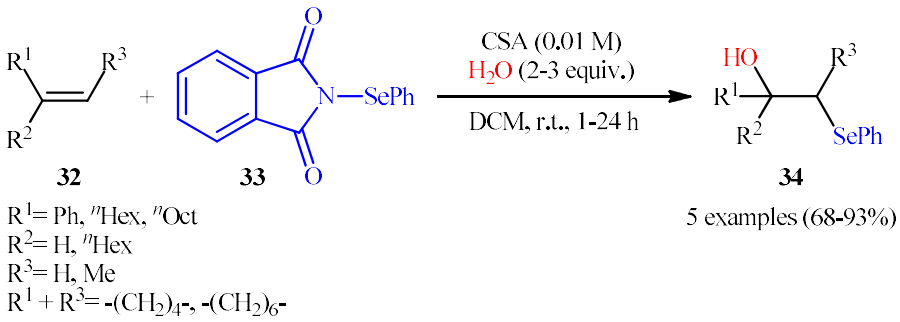
In 2018, the group of Santi disclosed that the treatment of styrene derivatives **30** with diphenyl diselenide **2** in the presence of 1 equiv. of oxone in binary solvent MeCN/H_2O with ratio 2:1 at 50 °C afforded the corresponding β-hydroxy selenide derivatives **31** in poor to excellent yields, ranging from 22% to 95%, through a Markovnikov addition procedure (Scheme 15) [27]. Unfortunately, using aliphatic alkenes under the same conditions led to much lower yields or even no desired product at all. By this approach, β-methoxy-selenides were also obtained in moderate to excellent yields at room temperature in an open flask, starting from alkenes and using methanol as both nucleophile and solvent.



Scheme 15. Santi's synthesis of β-hydroxy selenides **31**.

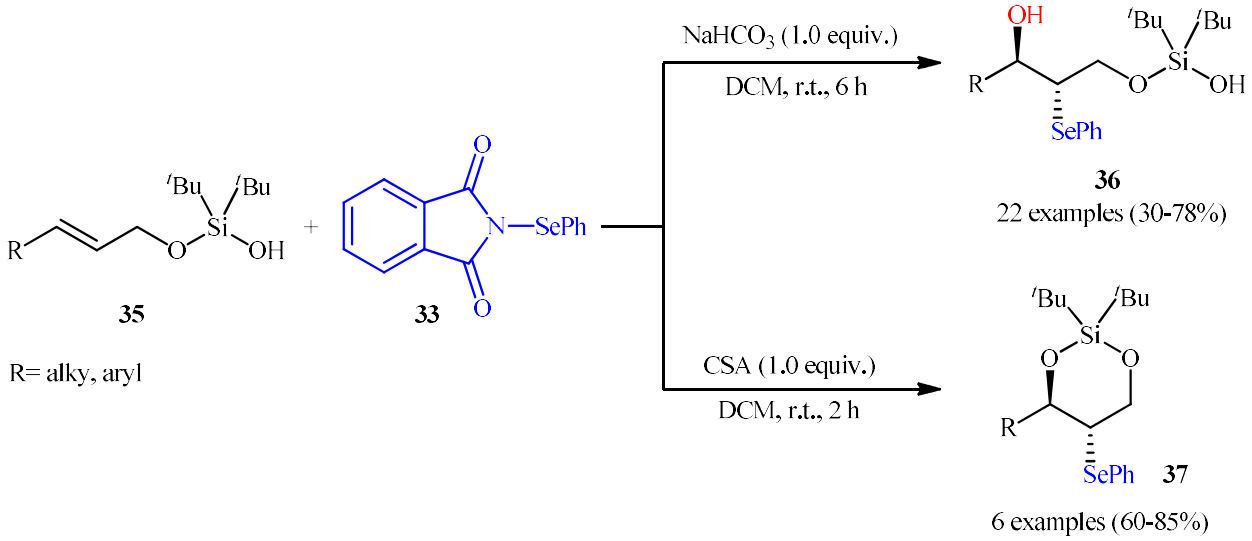
7. Acid/base-catalyzed/mediated reactions

N-(Phenylseleno)phthalimide is a commercially available versatile selenamide reagent which was widely applied as selenating agent in hydroxyselenation of alkenes under acidic conditions [28-30]. The first mention of the synthesis of β-hydroxy selenides through the acid-catalyzed hydroxyselenation of alkenes using *N*-(phenylseleno)phthalimide can be found in a 1979 paper by Nicolaou *et al* [31]. They showed that treatment of simple alkenes **32** with *N*-(phenylseleno)phthalimide **33** in the presence of 2-3 equivalents of water and a catalytic amount of camphorsulfonic acid (CSA) in DCM at room temperature resulted in the corresponding β-hydroxy selenides **34** in good to excellent yields through a Markovnikov addition procedure (Scheme 16). Similar results were also obtained by using *N*-phenylseleno-succinimide instead of *N*-(phenylseleno)phthalimide under the same conditions. Later, this reaction has been successfully applied by Katsuura and Snieckus as the key strategic step in synthesis of ochromycinone, a natural antibiotic and a STAT3 inhibitor [32].



Scheme 16. Nicolaou's synthesis of β-hydroxy selenides **34**.

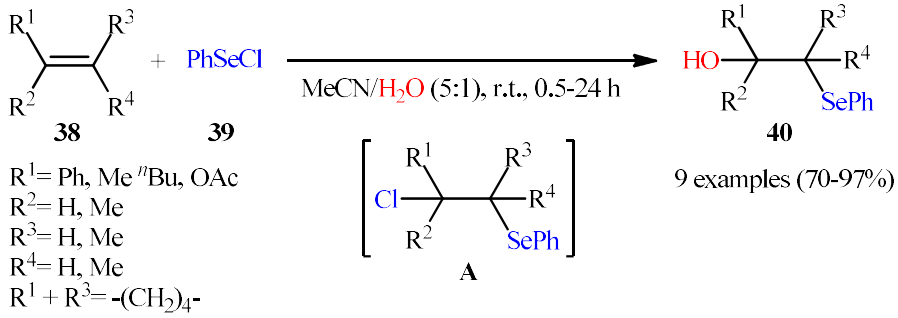
Recently, in a significant contribution in this field, Joshi and Sathyamoorthi developed an appealing hydroxyselenylation and silanoxyselenylation reaction of allylic silanols **35** using *N*-(phenylseleno)phthalimide **33** as the selenylating agent to afford selenohydrin silanols **36** and 5-(phenylselanyl)-1,3,2-dioxasilinane derivatives **37**, respectively [33]. When the reaction occurs under basic conditions, hydroxyselenylation proceeds with >20:1 regioselectivity. However, under acidic conditions, the hydroxyselenylation pathway is blocked and tethered silanoxyselenylation products are obtained exclusively (Scheme 17).



Scheme 17. Joshi-Sathyamoorthi's synthesis of selenohydrin silanols **37** and 5-(phenylselanyl)-1,3,2-dioxasilinanes **38**.

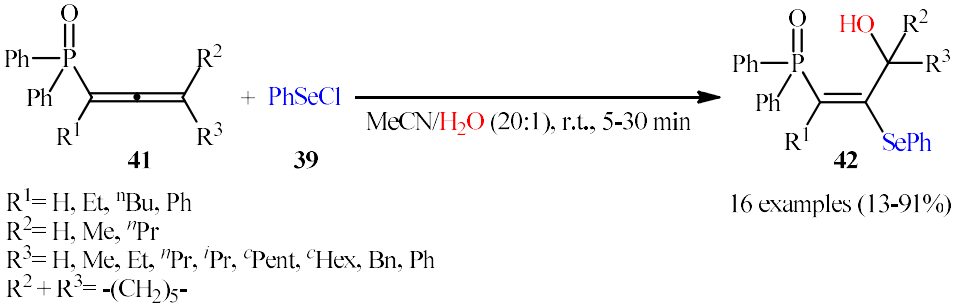
8. Catalyst-free reactions

In 1980, Uemura's research group developed a catalyst-free hydroxyselenation reaction of alkenes **38** using phenylselenyl chloride **39** as the selenating agent [34]. In the absence of any additive, all the four kinds of alkenes (terminal, 1,1-disubstituted, 1,2-disubstituted, 1,1,2-trisubstituted, and 1,1,2,2-tetrasubstituted alkenes) successfully underwent regioselective hydroxyselenation to generate corresponding β-hydroxy selenides **40** in good to excellent yields (Scheme 18). Regarding the regioselectivity of this transformation, in all examples the selenyl group selectively attacked to the less hindered carbon atom of the C=C bond. According to the authors, this reaction probably proceeds *via* a β-chloro selenide intermediate **A**. Later, further examples of β-hydroxy selenide synthesis using a similar principle were reported by other groups [35, 36, 37]. However, till now this chemistry has been limited to the use of phenylselenyl chloride and the utility of other aryl/alkyl-selenyl halides has not yet been explored in this transformation.



Scheme 18. Uemura's synthesis of β-hydroxy selenides **40**.

In 2009, Fu and Ma along with their co-workers investigated the similar hydroxyselenation reaction using 1,2-allene derivatives [38]. By employing 1-phenylocta-1,2-dienyl diphenyl phosphine oxide as the model substrate, various solvents (DCM, $MeNO_2$, MeCN, EtOAc, toluene, $MeCN/H_2O$, THF/H_2O, DMF/H_2O, Me_2CO/H_2O, $EtOH/H_2O$) were carefully screened. The results indicated that the system $MeCN/H_2O$ (20:1) was the most appropriate solvent for this conversion. Under the optimized conditions [PhSeCl (1.5 equiv.), $MeCN/H_2O$ (20:1), r.t.] a diverse array of 3-hydroxy-2-phenylselanyl-1(*E*)-alkenyl diphenyl phosphine oxides **42** were selectively obtained in poor to excellent yields from the respective 1,2-allenyl phosphine oxides **41** (Scheme 19). The complete (*E*)-stereoselectivity of this reaction is believed to be determined by the neighboring group participation effect of the diphenyl phosphine oxide functionality.



Scheme 19. Fu-Ma's synthesis of 3-hydroxy-2-phenylselanyl-1(*E*)-alkenyl diphenyl phosphine oxides **42**.

9. Conclusion

β-Hydroxy selenides are a class of organoselenium compounds with great potential for use in different fields from medicinal chemistry to *agrochemistry* and organic synthesis. Their specific chemical and biological properties are attracting significant research attention to develop efficient routes for their preparation. As illustrated in this review, the direct hydroxyselenenylation of alkenes which provide a convenient strategy for the construction of β-hydroxy selenides has devoted a great deal of attention. Attractive features of this page of β-hydroxy selenide synthesis include (i) easily accessible starting materials; (ii) good functional group compatibility; (iii) high regio- and stereoselectivity, (iv) mild reaction conditions, and (v) short synthetic scheme. The following developments are highly desirable in the future: (i) discovery of novel selenenylating agents; (ii) development of anti-Markovnikov-selective hydroxyselenenylation methods; and (iii) investigation of the utility of other catalytic systems such as nanocatalysts, photocatalysts, metal–organic framework-based catalysts, and chiral catalysts.

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