

Catalytic Conversion of β,γ -Unsaturated Esters, Amides and Nitriles into γ -Alkoxy or γ -Hydroxy α,β -Unsaturated Derivatives induced by Persulfate Anion Oxidation of Diphenyl Diselenide

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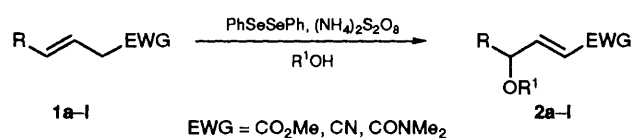
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The reaction of β,γ -unsaturated esters, amides and nitriles with catalytic amounts of diphenyl diselenide and an excess of ammonium persulfate in alcohols or in water affords γ -alkoxy or γ -hydroxy α,β -unsaturated derivatives, respectively, in good yields.

The recently reported catalytic conversion of alkenes into allylic ethers and esters, using diselenides having internal tertiary amines with copper(II) nitrate and sodium persulfate as an oxidizing agent,¹ prompted us to present our results on one-pot conversions of β,γ -unsaturated esters, amides and nitriles into γ -alkoxy or γ -hydroxy α,β -unsaturated derivatives which are effected by catalytic amounts of diphenyl diselenide and excess ammonium persulfate. We have reported that the oxidation of diphenyl diselenide by ammonium persulfate produces the strongly electrophilic phenylselenenyl sulfate, which can be successfully employed to effect the alkoxy-,² aryloxy-,³ hydroxy-² and amido-selenenylation⁴ of alkenes as well as the selenium induced ring closure reactions of unsaturated alcohols,⁵ amides,⁵ thioamides,³ 1,3-dicarbonyl compounds,⁵ oximes,⁶ acids⁵ and nitriles.⁴ Moreover, we have also observed that the alkyl phenyl selenides so formed, by reaction with ammonium persulfate in nucleophilic solvents, suffer deselenenylation giving the substitution products and regenerating the phenylselenenyl sulfate. This allowed us to develop a multi-step one-pot procedure to effect several interesting conversions of functional groups using an excess of ammonium persulfate and only catalytic amounts of diphenyl diselenide. In this way the conversions of alkenes into 1,1- and 1,2-dialkoxyalkanes,⁷ of alkynes⁸ and of methyl ketones⁹ into α -keto acetals and of 1,3-dicarbonyl compounds into the

corresponding 2,2'-dialkoxy derivatives¹⁰ were all efficiently effected. In all these cases the deselenenylation of the alkyl phenyl selenides, which are formed as intermediates, affords the products in which the PhSe group is substituted by an alkoxy group.

We now report the first example of this multi-step one-pot procedure in which the reaction of the intermediate alkyl phenyl selenides with the persulfate regioselectively evolves towards the elimination products. As shown in Scheme 1, the reaction of β,γ -unsaturated esters, amides and nitriles, **1a–1l** (0.5 mmol), with catalytic amounts of diphenyl diselenide (0.05 mmol) and an excess of ammonium persulfate (1.5 mmol) in alcohols or in water (30 ml) at 60 °C for a few hours, affords the γ -alkoxy or γ -hydroxy α,β -unsaturated derivatives, **2a–2l**, respectively, in good yields. The progress of the reaction was monitored by TLC, GC-MS and ¹H NMR. After the usual work up the reaction products were obtained

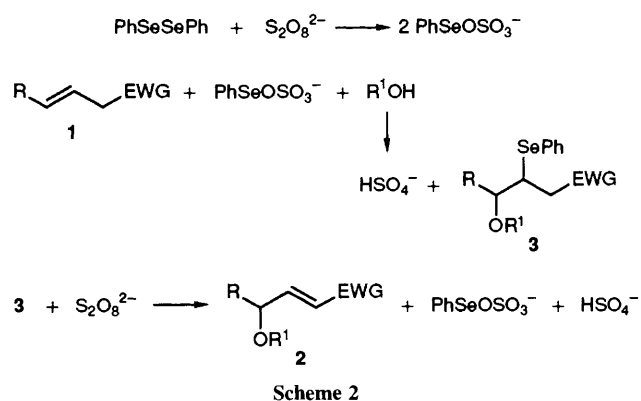


Scheme 1

Table 1 Conversion of alkenes **1** into allylic ethers or alcohols **2** catalysed by diphenyl diselenide^a

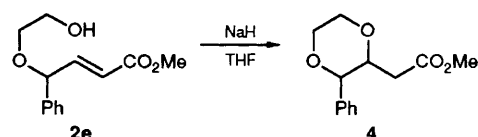
Alkene 1		Solvent ^b (R ¹ OH)	Reaction time/h	Product 2	Yield ^c (%)
EWG	R				
a	CO ₂ Me	Et	MeOH	a	90
b	CO ₂ Me	Et	H ₂ O	b	80
c	CO ₂ Me	Ph	MeOH	c	83
d	CO ₂ Me	Ph	H ₂ O	d	65
e	CO ₂ Me	Ph	(CH ₂ OH) ₂	e	75
f	CN	Me	MeOH	f	83
g	CN	Me	H ₂ O	g	71
h	CN	Ph	MeOH	h	63
i	CN	Ph	H ₂ O	i	61
j	CN	H	MeOH	j	23
k	CN	H	H ₂ O	k	25
l	CONME ₂	Ph	MeOH	l	60

^a An excess of ammonium persulfate was employed as the oxidizing agent in every case. ^b Acetonitrile was added as a co-solvent in the reactions run in water. ^c Calculated from isolated products after column chromatography.



in pure form by column chromatography on silica gel. † Most of the diphenyl diselenide was also recovered. The results of these experiments are summarized in Table 1. Good yields of compounds **2** are obtained in every case with the exception of the two reactions carried out with but-3-enenitrile. This is not surprising since this is a terminal alkene and the addition reaction should mainly give rise to the formation of the Markovnikov product which, by reaction with the persulfate, would probably give rise to other unidentified products. The elimination product which is observed in these cases is therefore only that deriving from the anti-Markovnikov addition product. Under the same experimental conditions simple unsubstituted alkenes gave rise to mixtures of products. Thus, the presence of the electron withdrawing group seems to be essential for the success of these reactions.

The proposed course of this reaction is indicated in Scheme 2. The phenylselenenyl sulfate, produced from the reaction of the diphenyl diselenide with ammonium persulfate, reacts with the starting alkene, **1**, to give the alkoxy or hydroxy selenenylated products, **3**. The reaction of these addition products with the persulfate affords the observed reaction products, **2**, and regenerates the electrophilic reagent. The intermediate formation of compounds **3** could be



Scheme 3

demonstrated by TLC and GC-MS. Moreover, these compounds were obtained as the sole reaction products when the reaction was carried out with stoichiometric amounts of diphenyl diselenide and ammonium persulfate. When dissolved in methanol or water and treated with ammonium persulfate, compounds **3** were converted into the elimination products **2** and phenylselenenyl sulfate was produced. The production of the electrophilic reagent was clearly demonstrated by the observation that when the same reaction was repeated in the presence of styrene, together with **2**, PhCH(OR¹)CH₂SePh was also isolated.

As suggested in previous work for similar alkyl phenyl selenides,⁷⁻¹⁰ the deselenenylation of compounds **3** probably occurs through the intermediate formation of selenium radical cations or selenonium ions which suffer fragmentation to give the phenylselenenyl sulfate and an alkyl cation. In the previous cases this was trapped by the nucleophilic solvent to give the substitution products. The presence of an electron withdrawing group in the α position is probably responsible for the evolution of the carbocation towards the elimination products which is observed in the present case. The formation of conjugated derivatives also explains the complete regioselectivity of these reactions. An alternative interpretation could imply that the reaction of **3** with ammonium persulfate affords a selenoxide intermediate which suffers the classical *syn*-elimination¹¹ giving **2** and selenenic acid. This has been suggested to occur in related reactions catalysed by diselenides, having internal tertiary amines, with copper(II) nitrate.¹ Although this possibility cannot be ruled out, also on the basis of the experimental evidence accumulated in previous work, which was carried out under identical experimental conditions,⁷⁻¹⁰ the above reported interpretation, involving the formation of a carbocation as the reactive intermediate, seems to explain better the course of the presently described reactions.

Compounds having structures similar to **2** can find several synthetic applications. For example, as indicated in Scheme 3, compound **2e** can be easily converted into the dioxane derivatives **4** (70% yield of a 1:1 mixture of the two stereoisomers) by simple treatment with sodium hydride in tetrahydrofuran (THF). Several other reactions are presently under investigation.

Compounds **2** can also be obtained using other known procedures.¹¹ Nevertheless, the method described in this paper presents several advantages because it requires easily available starting products and it occurs under extremely simple experimental conditions and in high yield. Very likely this method can also be applied to substrates having a more complex structure than that of the simple derivatives employed in the present investigation. Moreover, this new process contributes to a better knowledge of the chemistry of organoselenium compounds and, most interestingly, to their use as catalysts in the conversions of organic functional groups.

Further work in these multi-step one-pot conversions catalysed by diphenyl diselenide is presently underway in our laboratory. Of particular interest are the intramolecular versions of the reactions reported in the present paper which allow to easily synthesize butenolides, furan, dihydrofuran and several other derivatives.^{12,13}

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† Reaction products were fully characterized by ¹H and ¹³C NMR spectra and by GC-MS.

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