

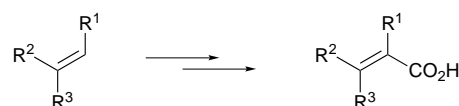
The free-radical addition of phenyl trichloromethyl selenide to alkenes: a new method for the regioselective carboxylation of alkenes

Thomas G. Back* and Kazimierz Minksztym

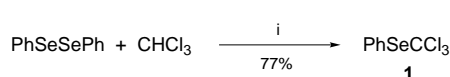
Department of Chemistry, University of Calgary, Calgary, AB, Canada, T2N 1N4

The free-radical addition of phenyl trichloromethyl selenide to alkenes affords 2-phenylseleno-1-trichloromethylalkanes, which can be converted into α,β -unsaturated carboxylic acids or amides by base-promoted dehydrochlorination, followed by [2,3]sigmatropic rearrangement of the corresponding selenoxides in the presence of water or diethylamine, respectively.

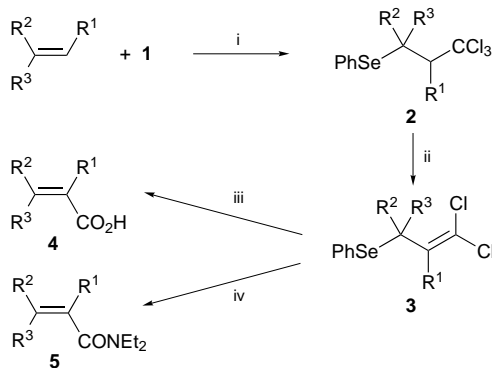
Free-radical 1,2-additions of selenium compounds of general structure PhSeX to alkenes and alkynes¹ provide a synthetically useful means for introducing the versatile phenylseleno group, as well as an additional functionality [e.g. X = SO₂Ar,² SePh,³ C(=O)R,⁴ SC(=O)Ph,⁵ and CHZ₂,⁶ where Z is an electron-withdrawing group] into the substrates. Free-radical additions of perhaloalkanes such as bromotrichloromethane are also well known.⁷ Moreover, PhSe group transfers to alkyl radicals occur with rates comparable to those of bromine atom transfers,⁸ suggesting that phenyl trichloromethyl selenide **1**⁹ should undergo free-radical additions similar to those of bromotrichloromethane. We now report the novel photo-initiated or thermally initiated radical additions of **1** to alkenes, followed by some illustrative further transformations of the trichloromethyl and phenylseleno moieties that permit the overall conversion of the alkene into the corresponding α,β -unsaturated carboxylic acid (or amide), as shown in Scheme 1. Other methods for the carboxylation of alkenes generally require the presence of



Scheme 1



Scheme 2 Reagents and conditions: i, 50% NaOH–H₂O, Adogen 464[®], O₂, 15–20 °C



Scheme 3 Reagents and conditions: i, *hν* or heat, AIBN; ii, Bu^tOK–THF, –30 or 10 °C; iii, 30% H₂O₂ H₂O, –30 °C; iv, MCPBA, CH₂Cl₂, –30 °C, then Et₂NH, room temp.

activating substituents to permit deprotonation of the alkene, or an existing functionality (e.g. halide, stannane) that provides a site for metallation, followed by reaction with carbon dioxide or

Table 1 Addition of **1** to alkenes^a

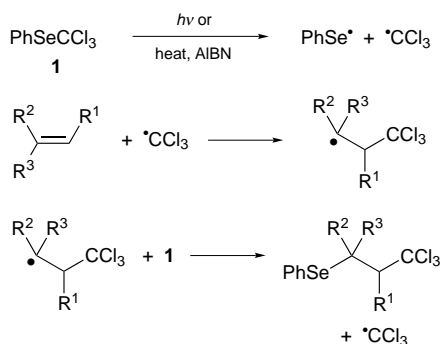
Alkene	Product	Yield (%)	<i>t</i> /h
		88 62 ^b 78 ^c	12 60 25
		75	13
		81	5
		65	13
		69	12
		60 ^d	19
		54 ^e	12
		43	17
		63 ^f	24
		87	19

^a All reactions were performed neat using photo-initiation and 5 equiv. of the alkene unless otherwise noted; isolated yields are reported. ^b Only 1.5 equiv. of the alkene was used. ^c Performed in benzene at 80 °C with 10 mol% of AIBN. ^d The diastereomeric ratio was 3.8 : 1, as determined by NMR integration. ^e The diastereomeric ratio was 4.2 : 1, as determined by NMR integration. ^f The *cis* : *trans* ratio was 1 : 1.8, as determined by NMR integration.

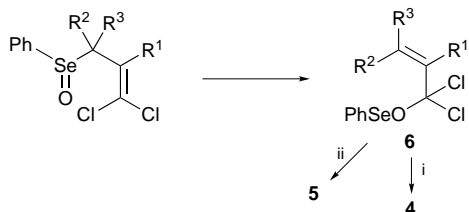
one of its synthetic equivalents.¹⁰ The present method permits the use of unactivated olefins.

Selenide **1** was conveniently prepared by a new method from the base-catalysed reaction of diphenyl diselenide with CHCl_3 (Scheme 2). Thus, a mixture of the diselenide, a catalytic amount of Adogen 464® (methyltrialkylammonium chloride), 50% aqueous NaOH and CHCl_3 was stirred for 9 h at 15–20 °C, while air was bubbled through the reaction mixture to recycle the byproduct selenolate (PhSe^-). The product was isolated in 77% yield by flash chromatography.

The free-radical 1,2-addition of **1** to various alkenes to give **2** was then effected as shown in Scheme 3 and Table 1. Monosubstituted alkenes afforded adducts **2a–e** with only traces (< 5%) of their corresponding regioisomers, as indicated by NMR analysis. Both *cis*- and *trans*-dec-5-ene produced **2f** as the same *ca.* 4:1 mixture of diastereomers. Cyclohexene furnished a mixture of *cis* and *trans*-adducts **2h** in a ratio of 1:1.8. Thus, the additions are highly regioselective, but only moderately stereoselective. β -Pinene underwent ring-opening during the addition to afford the rearranged 1,6-adduct **2i**. In general, the reactions were performed by irradiation of the reaction mixture, either neat or in benzene solution, containing an excess (usually five-fold) of the alkene with a 300 W incandescent lamp. The use of a smaller excess of the alkene resulted in lower yields and required longer reaction times. The reaction was also performed in the case of **2a** in benzene at



Scheme 4



Scheme 5 Reagents and conditions: i, H_2O ; ii, Et_2NH , then H_2O

Table 2 Preparation of allylic selenides **3**, carboxylic acids **4** and amides **5** from **2**

Adduct	R^1	R^2	R^3	Isolated yields (%)		
				3	4	5
2a	H	C_6H_{13}	H	92	91	73
2b	H	Bu^t	H	90	84	50
2f	Bu^n	Bu^n	H	92	81	59
2g	$-\text{[CH}_2\text{]}_4-$		H	86	60	50

80 °C in the presence of 10 mol% of the radical initiator AIBN. These results suggest a free-radical chain process in which cleavage of the $\text{Se}-\text{CCl}_3$ bond initiates the reaction, followed by addition of the trichloromethyl radical to the less substituted alkenic atom, and finally transfer of the PhSe group from **1** to the resulting 2-alkyl radical (Scheme 4).

Several of the adducts **2** were then transformed into allylic selenides **3** by dehydrochlorination with KO^tBu in THF at -30 °C (except for **3f**, which required 6 h at 10 °C), and finally into α,β -unsaturated carboxylic acids **4** by oxidation and *in situ* [2,3]sigmatropic rearrangement (Scheme 3) of the resulting selenoxides.¹¹ Products **4a**, **4b** and **4f** were obtained as the *E*-isomers with high stereoselectivity. When Et_2NH was present during the latter step, the corresponding diethylamides were obtained instead. These results are shown in Table 2. Presumably, the sigmatropic rearrangement produces **6** initially, which then hydrolyses to the carboxylic acid **4** (Scheme 5). On the other hand, **6** reacts preferentially by aminolysis in the presence of diethylamine to afford the amide **5** instead of **4** after aqueous workup.

All new compounds reported here gave IR, ^1H NMR, ^{13}C NMR and low and high resolution mass spectra consistent with their structures.

These results demonstrate that the free-radical additions of readily available selenide **1** to alkenes occur efficiently and with high regioselectivity. Moreover, when the above process was used in conjunction with base-promoted dehydrochlorination and [2,3]sigmatropic rearrangement of the corresponding selenoxides, a novel method for the overall regioselective carboxylation of alkenes was achieved.

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Footnote and References

* E-mail: tgback@acs.ucalgary.ca

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