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The Utilization of Free-Radical Group-Transfer Cyclizations

Zong-Ting Chen, Fen-Ling Zhan, and Ji-Wei Gao

Research Institute of Elemento-Organic Chemistry, Nankai University, Tianjin 300071, P.R. China

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ABSTRACT: *O-Allyl-Se-phenylselenosalicylates, O-allyl-Se-alkylselenosalicylates, and the O-propargyl derivatives can generate free radicals under white light irradiation, and cyclization reactions are described that involve phenylseleno or alkylseleno group transfer.*
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INTRODUCTION

Carbon–carbon bond-forming reactions are an indispensible part of organic synthetic chemistry and are of critical importance in creating carbon skeletons of special structure [1,2]. In addition to polar reactions and nonpolar pericyclic reactions, free-radical carbon–carbon bond-forming reactions constitute an active and developing field.

One of the main methods of formation of carbon–carbon bonds through radical reactions involves addition of a radical to an alkene or alkyne [3,4]. In the 1980s, free-radical cyclization reactions involving phenylselenoesters were reported [5–7]. Such reactions were initiated by AIBN and tributylstannane. In these reactions, free radicals produced were reduced by tributylstannane. In order to avoid the necessity of reduction by tributylstannane, we have used hexabutylditin instead of tributylstannane, hoping to obtain a nonreductive carbon–carbon bond-forming reaction.

Correspondence to: Zong-Ting Chen.
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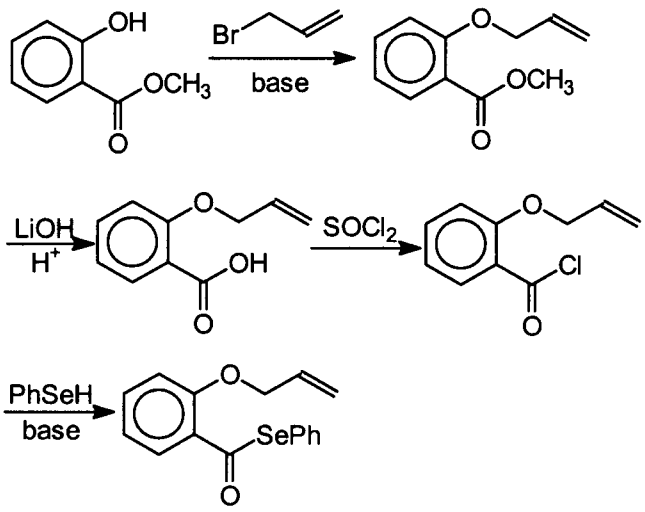
RESULTS AND DISCUSSION

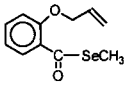
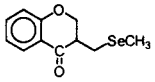
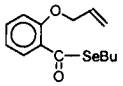
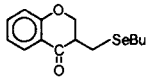
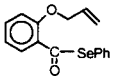
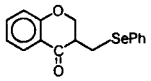
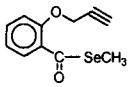
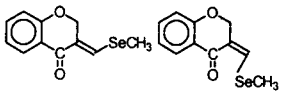
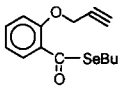
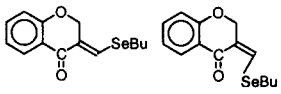
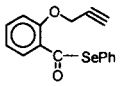
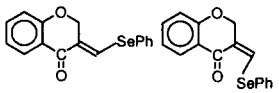
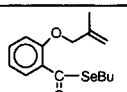
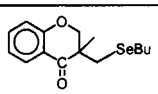
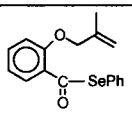
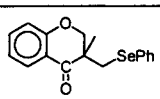
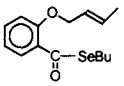
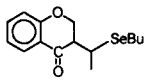
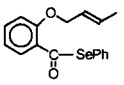
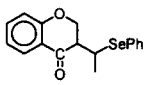
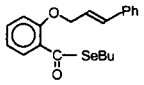
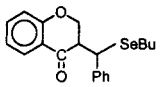
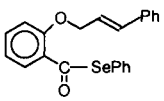
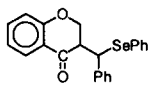
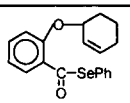
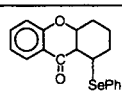
A series of O-allyl-Se-phenylselenosalicylates, O-allyl-Se-alkylselenosalicylates, and the O-propargyl derivatives were prepared. The synthetic method is shown in Scheme 1. The methylseleno ester was prepared by treating methyllithium with selenium powder under nitrogen gas in dry THF in a cooling bath of ice salt. The lithium methylselenide formed was reacted directly with the appropriate acyl chloride. Butyl selenol was prepared by treating butylmagnesium bromide with selenium in ether and subsequent acidification (shown in Scheme 2).

The experiments were carried out under two reaction conditions: (1) use of AIBN and hexabutylditin and (2) use of white light irradiation and hexa-

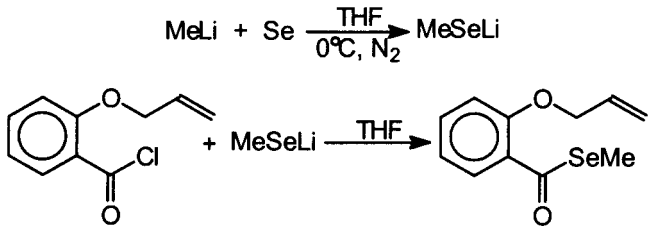


SCHEME 1

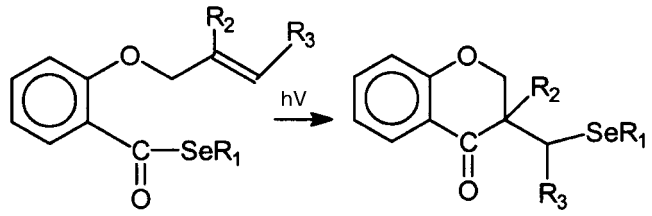
TABLE 1 Free-Radical Group-Transfer Cyclizations

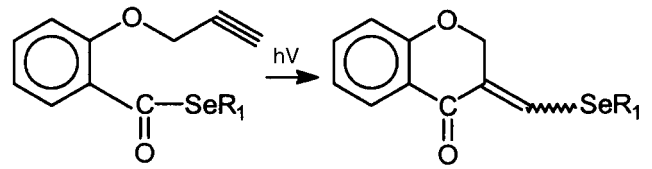
Entry	Acyl selenide	Method	Products	Isolated Yield(%)
a		A		44
b		B		67
c		A		57
d		A	 75 : 25	74(0.3M) 43
e		B	 70 : 30	49
f		A	 89 : 11	49
g		B		63
h		B		57
i		B		0
j		B		0
k		B		0
l		B		0
m		B		0

Method A: C_6D_6, in NMR tube. $Bu_3SnSnBu_3$: reactant (molar ratio 1:10), concentration 0.5 M, G.E. 275 W Sunlamp. The distance from the NMR tube to the lamp 10 mm, 70°C, irradiation about 7–13 hours, argon protected. Method B: C_6H_6, in test tube, 0.05 M, 250 W high-pressure mercury fluorescent lamp (take off the fluorescent powder in the process of manufacture). The distance from the test tube to the lamp 30 mm, irradiated about 20 hours, ~70°C, argon protected.
The isomer ratios were determined by NMR.

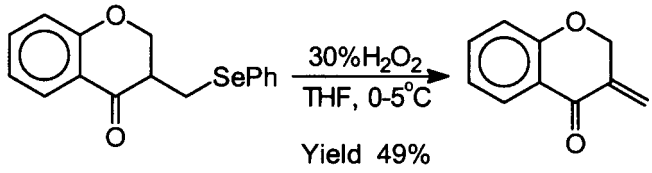


SCHEME 2

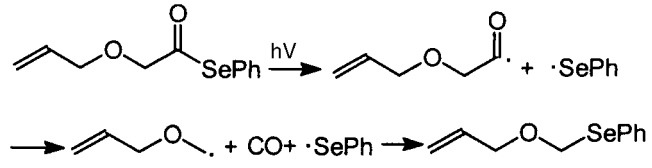




SCHEME 3



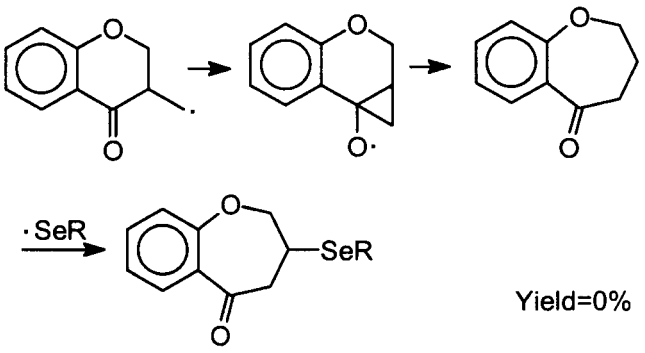
SCHEME 4



SCHEME 5

butylditin. Under the second set of conditions, the acyl phenylseleno and acyl alkylseleno compounds underwent homolytic cleavage. The acyl free-radical intramolecularly added to an alkene or an alkyne. Because those reactions were nonreductive, the phenylseleno and alkylseleno groups were transferred to a double or triple bond (shown in Scheme 3).

Experiments make clear that, under the second set of conditions, the free-radical group-transferring annulation reactions proceeded successfully, and the use of hexabutylditin was not necessary. In the formed molecules, the phenylseleno groups can be removed by the action of hydrogen peroxide, thus providing a new double bond, therefore augmenting the molecular residual functionality (shown in Scheme 4) [1,8,9].

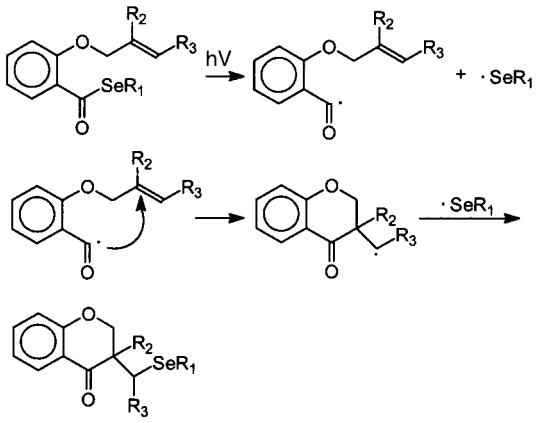


SCHEME 6

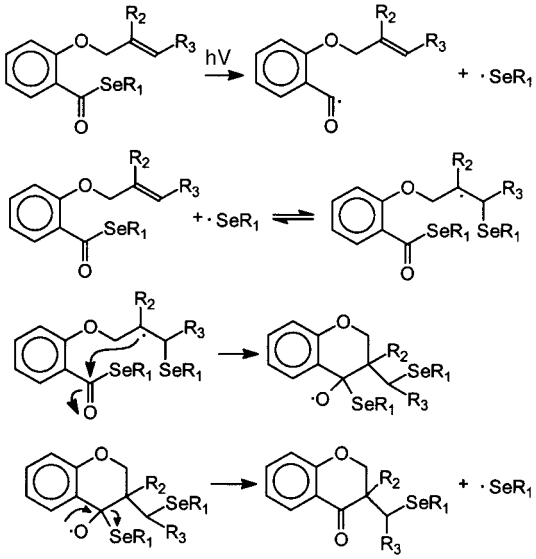
These group-transfer annulations can only occur when the acyl group is connected to a benzene ring to provide enough stability. If the acyl group is connected to an alkyl group as shown in Scheme 5, the acyl carbonyl group will be lost under the same conditions to provide the decarbonylation product instead of the cyclization product. Some aliphatic acyl selenides were tested as materials in the same annulation reaction, but without success.

There are at least two possible mechanisms to be considered. Acyl selenide homolysis by white light irradiation is the initial step in both mechanisms I and II to produce an acyl radical and a phenylseleno radical (shown in Scheme 7). In mechanism I, an acyl radical attacks the double bond to form a 6-exo intermediate, which might be changed to a 7-endo intermediate under the same reaction conditions [10,11]. However, the possible 7-endo product was not found in the reaction mixture (shown in Scheme 6). We noticed that, as shown in entries i to m, the unsaturated bonds with substituents at the terminal end did not undergo this reaction. Thus, mechanism I does not explain this result. In mechanism II, the phenylseleno radical adds to the unsaturated bond to form an adduct, the stability of which is determined by whether there are substituents at the terminal end. If the terminal group were alkyl, the adduct would be very unstable, easily revert to starting materials or directly decompose, and could not undergo the next procedure. This mechanism might be similar to the mechanism for germyl radical transfer reactions [12] (shown in Scheme 7).

Mechanism I



Mechanism II



$R_1Se\cdot + \cdot SeR_1 \longrightarrow R_1SeSeR_1$

R_1 =phenyl, alkyl; R_2 =H, alkyl; R_3 =H, phenyl, alkyl.

R_3=H, yield>0%; R_3=phenyl, alkyl, yield=0%.

SCHEME 7

ACKNOWLEDGMENT

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REFERENCES

[1] D. J. Hart, *Science, 223,* 1984, 883.
[2] A. L. J. Beckwith, *Tetrahedron, 37,* 1981, 3073.
[3] D. J. Hart, K. Kanai, *J. Am. Chem. Soc., 105,* 1983, 1255.
[4] M. D. Bachi, E. Bosch, *Heterocycles, 28,* 1989, 579.
[5] M. D. Bachi, E. Bosch, *Tetrahedron Lett., 27,* 1986, 641.
[6] M. D. Bachi, E. Bosch, *Heterocycles, 28,* 1989, 583.
[7] D. L. Boger, R. J. Mathvink, *J. Org. Chem, 53,* 1988, 3377.
[8] Y. Ueno, K. Chino, M. Okawara, *Tetrahedron Lett., 23,* 1982, 2575.
[9] S. Hanessian, P. J. Hodges, S. P. Sahoo, P. J. Roy, *Tetrahedron Lett., 27,* 1986, 2949.
[10] P. Dowd, S.-C. Choi, *Tetrahedron, 45,* 1989, 77.
[11] A. L. J. Beckwith, D. M. O'Shea, S. W. Westwood, *J. Am. Chem. Soc., 110,* 1988, 2565.
[12] D. P. Curran, H. Liu, *J. Org. Chem., 56,* 1991, 3463.
[13] All these compounds gave satisfactory results on elementary analysis or exact mass spectrometry.
[14] ^{1}H NMR of these compounds as follows: ^{1}H NMR ($CDCl_3$, δ) (a) 2.05 (s, 3H, $SeCH_3$), 2.63–2.71 (m, 1H, CHSe), 2.84–2.93 (m, 1H, CH), 2.97–3.02 (m, 1H, CHSe), 4.44–4.64 (m, 2H, OCH_2), 6.95–7.89 (m, 4H, Arom H); (b) 0.84 (t, 3H, CH_3, J = 7.3 Hz), 1.28–1.64 (m, 4H, CH_2CH_2), 2.55 [t, 2H, $SeCH_2$(Bu) J = 7.3 Hz], 2.58–2.65 (m, 1H, CHSe), 2.70–2.82 (m, 1H, CH), 2.90–2.98 (m, 1H, CHSe), 4.40–4.53 (m, 2H, OCH_2), 6.86–7.78 (m, 4H, Arom H); (c) 2.90 (m, 2H, CH_2Se), 3.45 (m, 1H, CH), 4.40–4.65 (m, 2H, OCH_2), 6.93–7.89 (m, 9H, Arom H); (d) 2.42 (s, 2.25H, *E*-isomer $SeCH_3$), 2.57 (s, 0.75H, *Z*-isomer $SeCH_3$), 5.12 (d, 1.5H, OCH_2, J = 1.4 Hz), 5.13 (d, 0.5H, OCH_2, J = 1.4 Hz), 7.10–8.17 (m, 4H, Arom H), 7.66 (d, 0.75H, *E*-isomer = −H, J = 1.4 Hz), 8.36 (d, 0.25H, *Z*-isomer = −H, J = 1.4 Hz); (e) 0.91 (t, 3H, CH_3 J = 7.3 Hz), 1.31–1.83 (m, 4H, CH_2CH_2), 2.73 (t, 2H, $SeCH_2$, J = 7.3 Hz), 4.93 (s, 2H, OCH_2), 6.91–8.03 (m, 4H, Arom H), 7.68 (s, 0.7H, *E*-isomer = −H), 8.23 (s, 0.3H, *Z*-isomer = −H); (f) 4.98 (d, 2H, OCH_2, J = 1.4 Hz), 6.95–8.01 (m, 9H, Arom H), 7.73 (t, 0.9H, *E*-isomer = −H, J = 1.4 Hz), 8.30 (t, 0.1 H, *Z*-isomer = −H, J = 1.4 Hz); (g) 0.86 [t, 3H, CH_3(Bu), J = 7.3 Hz], 1.19 (s, 3H, CH_3), 1.33–1.63 (m, 4H, CH_2CH_2), 2.55 [t, 2H, $SeCH_2$(Bu), J = 7.3 Hz], 2.67, 2.88 (AB, q, 2H, $SeCH_2$, J = 13.5 Hz), 4.07, 4.45 (AB, q, OCH_2, J = 11.4 Hz), 6.90–7.89 (m, 4H, Arom H); (h) 1.26 (s, 3H, CH_3), 3.12, 3.33 (AB, q, 2H, CH_2Se, J = 12.5 Hz), 4.15, 4.45 (AB, q, 2H, OCH_2, J = 11.5 Hz), 6.99–7.60 (m, 9H, Arom H).