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RADICAL ADDITION OF DIETHYL (2-PHENYLSELENO)PROPANEDIOATE TO OLEFINS

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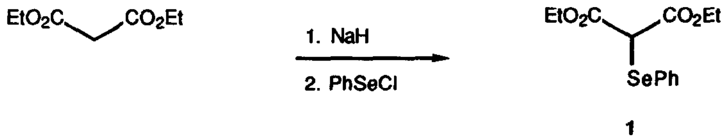
Abstract: The diethyl malonyl radical can be generated via the photolysis of diethyl (2-phenylseleno)propanedioate. This radical, in turn adds to olefins, and the radical chain process is propagated by phenyl selenide transfer, leading to products arising from formal addition of diethyl (2-phenylseleno)propanedioate.

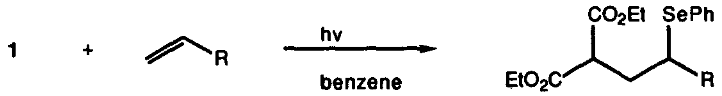
One of the more interesting and potentially useful recent developments in the organic chemistry of free-radicals has involved the formation of carbon-carbon bonds via atom transfer reactions. Curran and others have demonstrated the utility of iodine and bromine transfer radical cyclizations[1]. Curran[1f,g] and Giese[2] have demonstrated the addition of iodo and bromomalonates, respectively, to olefins, exemplifying intermolecular reactions which proceed with halogen transfer. In Giese's studies the radical addition is followed by spontaneous elimination of HBr yielding substitution products. The free-radical selenosulfonation of olefins proceeding with phenyl selenide transfer is also known[3]. We wish to report what we believe to be the first example of a mechanistically analogous radical carbon-carbon bond forming reaction proceeding with transfer of the phenyl selenide functional group.

The key reagent for this reaction, diethyl (2-phenylseleno)propanedioate (**1**) has previously been synthesized via the reaction of sodium phenyl selenide with diethyl bromomalonate[4]. We have found however, that this reagent is better prepared upon reaction of the anion of diethyl malonate with phenylselenenyl chloride[5]. This procedure frequently yielded a product contaminated with minor amounts of unreacted diethyl malonate and the by-product diethyl 2,2-di(phenylseleno)propanedioate which could be only removed via careful chromatography. However, in subsequent reactions where **1** was used in excess, the presence of these impurities did not have deleterious effects on the product yield or purity .



1

We have found that irradiation of a solution consisting of **1** and an olefin in benzene with a 275-W sunlamp generates good to excellent yields of addition products in most cases, as generalized in the following equation.



The apparatus employed consisted of a 5- or 10-mL flask outfitted with a reflux condenser and a stirbar. The olefin and **1** were added to the round-bottomed flask, dissolved in 2 mL of benzene, and were degassed by bubbling Ar through the mixture for 15-20 min. The sunlamp was placed 6-8 inches from the flask, and the apparatus was wrapped in aluminum foil. The reaction was allowed to heat to reflux during irradiation. In most cases, the reaction proceeded to completion overnight. The most satisfactory yields were usually obtained upon use of a 3:1 ratio of selenide:olefin (condition A). In some cases, particularly when dealing with volatile or polymerization-prone olefins, a 1:5 ratio of selenide:olefin was used (condition B). In both cases the concentration of **1** was 0.5 M in benzene.

While method B did generate higher yields of addition products in some cases, in general, reaction conditions under which **1** was the limiting reagent usually proved less satisfactory. This was due to the unavoidable radical disproportionation reaction leading to consumption of **1** as shown below. When electron deficient olefins such as butyl vinyl ketone and cyclohexenone, which are known to be resistant to attack by the diethyl malonyl radical[6], were used as substrate, only these disproportionation products were observed.

$$\mathbf{1} \xrightarrow[\text{benzene}]{\text{hv}} \text{PhSeSePh} + (\text{EtO}_2\text{C})_2\text{CHCH}(\text{CO}_2\text{Et})_2$$

Table I summarizes the successful applications of this reaction. All yields shown are of products isolated and purified by medium pressure liquid chromatography. Products were characterized by their ^{1}H NMR, IR, the proper molecular ion in the mass spectrum, and by satisfactory combustion analysis.

In all cases where a terminal olefin was used, the only product obtained and identified was the isomer shown, arising from the presumed attack of the diethyl malonyl radical on the unsubstituted olefinic carbon. Analysis of the crude product mixtures by GC/MS failed to indicate the presence of any other isomeric products.

In order to provide further evidence for the proposed radical mechanism the following experiments were performed: When a benzene solution of **1** and allyl benzoate was heated to reflux in the absence of light, no reaction occurred. However, upon addition of a catalytic portion of the radical initiator AIBN, the reaction did proceed, albeit much more slowly than in the photochemically initiated reactions. Thus, we believe that the results indicate that the reactions proceed via the proposed radical mechanism.

In summary, we have demonstrated a new radical carbon-carbon bond forming reaction involving phenyl selenide transfer. This reaction should prove of value due to the often good yields of addition products obtained as well as the versatility of the phenyl selenide moiety for further transformations.

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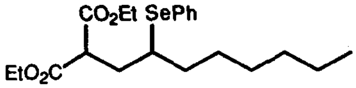
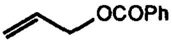
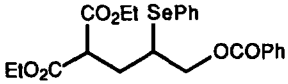
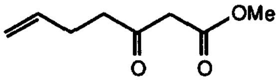
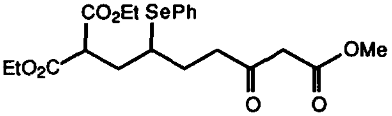
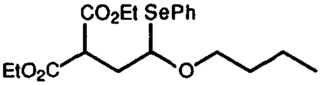
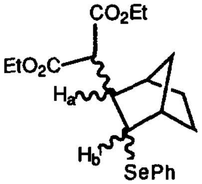
Table I

Substrate	Product	Yield (Method)
		95% (A)
		88% (A)
		74% (A)
		65% (B)
		85% (B)[7]

References and Notes

1. (a) Curran, D. P.; Chen, M. -H.; Kim, D. *J. Am. Chem. Soc.* **1986**, *108*, 2489. (b) Curran, D. P.; Kim, D. *Tetrahedron Lett.* **1986**, *27*, 5821. (c) Curran, D. P.; Chen, M. -H. *J. Am. Chem. Soc.* **1987**, *109*, 6558. (d) Curran, D. P.; Chang, C. -T. *J. Org. Chem.* **1989**, *54*, 3140. (e) Barth, F.; O-Yang, C. *Tetrahedron Lett.* **1990**, *31*, 1121. (f) Curran, D. P. *Synthesis* **1988**, 489. (g) Curran, D. P.; Chen, M. -H.; Spletzer, E.; Seong, C. M.; Chang, C. -T. *J. Am. Chem. Soc.* **1989**, *111*, 8872. (h) Curran, D. P.; Chen, M. -H.; Kim, D. *J. Am. Chem. Soc.* **1989**, *111*, 6265.

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4. (a) Stockel, R. F.; Dumas, E. U. S. Patent 4 536 571, 1985. (b) Stockel, R. F.; Dumas, E. U. S. Patent 4 617 189, 1986.

5. **1** was synthesized by the following procedure: A 0.80-g (20-mmol) portion of NaH (60% by wt in mineral oil) was suspended in 40 mL of dry THF under Ar and cooled to 0 °C. Diethyl malonate (3.2 g, 20 mmol) was added via syringe. Upon completed evolution of H_2, the mixture was cooled to -25 °C. PhSeCl which had

been freshly recrystallized from hexane (0.96 g, 5mmol) was added in one portion. The mixture was stirred overnight, gradually warming to room temperature. Ether (100 mL) was added, and the resulting mixture was washed successively with 100 mL of 0.5 M HCl, water, and brine. The resulting organic phase was dried over anhydrous $MgSO_4$, filtered, and solvents were removed by rotary evaporation. Excess diethyl malonate was removed by Kugelrohr distillation (80 °C, approx 1mm) and the resulting undistilled oil was futher purified by medium pressure liquid chromatography with 5% EtOAc in hexane to give 0.85 g (2.7 mmol, 54%) of **1** as a clear, colorless liquid. ^1H NMR (300 MHz, $CDCl_3$) 7.2-7.8 ppm (m, 5 H), 4.5 ppm (s, 1 H), 4.18 (q, 4 H), 1.22 (t, 6 H).

6. Giese, B. *Radicals in Organic Synthesis: Formation of Carbon-Carbon Bonds* ; Pergamon: Oxford, 1986.

7. In this case only two of the four possible stereoisomers were observed by GC-MS (0.2 mm x 12 m methyl silicone column) in a 58:42 ratio. After purification by HPLC, NMR analysis of the coupling constants between the H_a and H_b showed the major isomer to be a cis isomer (J_{ab} = 7.1 Hz) and the minor isomer to be trans (J_{ab} = 5.8 Hz).

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