Pergamon

Tetrahedron Letters 39 (1998) 8413–8416

TETRAHEDRON LETTERS

Carbamoyl Radicals from Se-Phenylselenocarbamates: Intramolecular Additions to Alkenes

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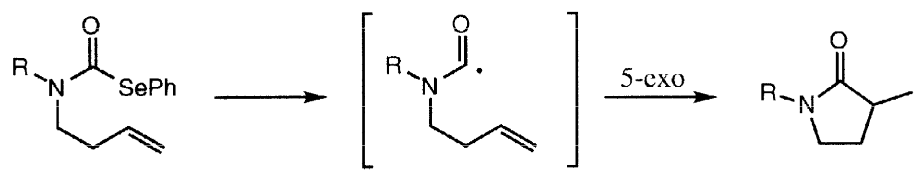
Received 21 July 1998; accepted 21 August 1998

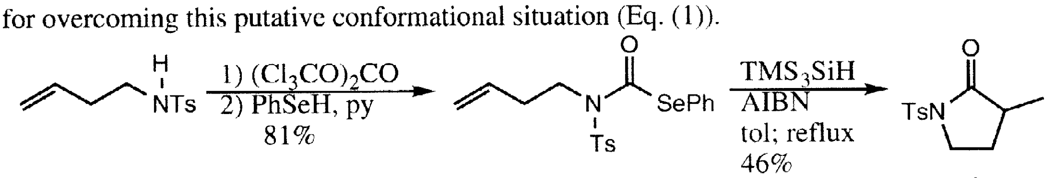
Abstract: A series of 5 *exo*-trig cyclizations of carbamoyl radicals generated from readily available Se-phenylselenocarbamates is reported. Kinetic studies indicate that the rate constant of this cyclization exceeds $1 \times 10^8 s^{-1}$ in several cases.

Acyl radical cyclization has recently emerged as a useful tactic for ring construction in organic synthesis,[1] and successful variations on this theme include the use of alkoxycarbonyl[2] and imidoyl[3] radical donors for producing lactones and cyclic amines, respectively. Less well-studied are carbamoyl radical additions to alkenes to afford lactam products.[4] To date, acylcobalt salophen reagents are among the most common carbamoyl radical precursors in the literature.[4a,b] In this report we disclose the use of Se-phenylselenocarbamates as convenient and effective alternative precursors for the production of carbamoyl radicals.

Scheme I



Initial efforts focused on accessing the requisite selenocarbamates via addition of PhSeH to the corresponding isocyanates followed by attempted radical cyclization mediated by either n-Bu_3SnH or TMS_3SiH. In all cases only formamide[5] and amine products resulting from reduction and decarbonylation, respectively, were isolated. The predominance of rotamers unfavorable to ring formation in the intermediate secondary carbamoyl radicals is a possible reason for the failure of these substrates to cyclize.[6] This would be particularly true if the interconversion of the reactive and unreactive carbamoyl radicals was slow on the scale of the radical lifetimes.[7,8] In response to this difficulty, the corresponding tertiary carbamates (R ≠ H) were then examined as a potential means for overcoming this putative conformational situation (Eq. (1)).



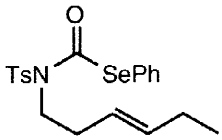
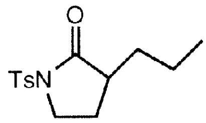
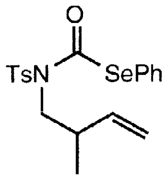
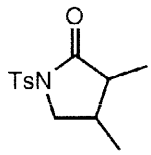
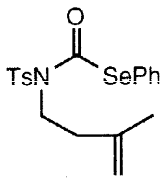
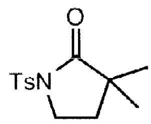
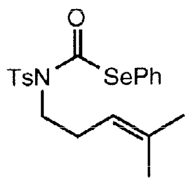
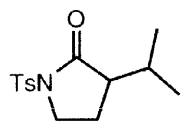
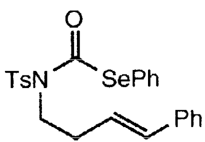
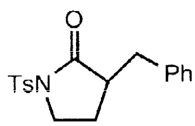
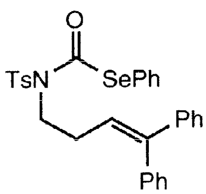
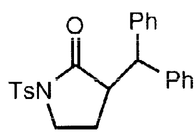
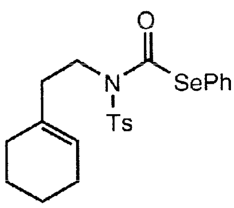
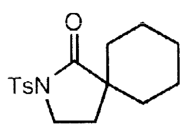
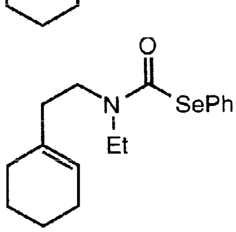
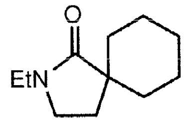
(1)

1 2 3

The more highly substituted selenocarbamates required for this study were best prepared in a slightly different fashion than was employed for the secondary carbamates. Thus, treatment of N-tosylamine **1** with triphosgene followed by addition of phenylselenol afforded the N-tosyl-Se-phenylselenocarbamate **2**[9] in quite good yield. Exposure of this material to excess TMS_3SiH in refluxing toluene led in serviceable yield to the

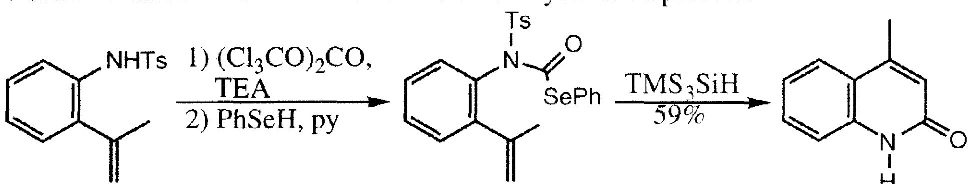
0040-4039/98/$ - see front matter
PII: S0040-4039(98)01830-9

Table I Radical Cyclization of Se-Phenylselenocarbamates

Entry	Selenocarbamate	Conditions[a]	Product[b]	Yield (%)
1		A		68
2		A		41[c]
3		A		31
4		A		66
5		B		55
6		B		51
7		A		45
8		A		49

[a] Conditions "A": TMS_3SiH, AIBN, toluene, reflux; Conditions "B": Bu_3SnH, $(Bu_3Sn)_2$, sunlamp, benzene, heat; Ref. 10. [b] Ref. 9. [c] Produced as a mixture of isomers.

expected butyrolactam **3**.[9] In contrast, Bu_3SnH afforded the corresponding formamide product along with lesser amounts of amine.[11] Other examples that illustrate the scope of this cyclization protocol are compiled in Table I. In most cases examined during this study, $(TMS)_3SiH$/AIBN in refluxing toluene provided superior yields of cyclized products, however, $Bu_3SnH/(Bu_3Sn)_2$/hv conditions proved most effective for securing the requisite lactams in Entries 5 and 6.[12] Typically, cyclization was effected on N-tosyl substituted substrates, but N-alkylselenocarbamates are also viable radical precursors as evidenced by the result in Entry 8, thus discounting any unusual electronic influence of the sulfonamide on the cyclization process.[13]



4 (2)

Inspection of the entries in Table I reveals that a range of 5-*exo* cyclizations can be achieved starting from selenocarbamates, unfortunately attempts to extend the process to the corresponding 6-*exo* cyclizations failed to deliver significant quantities of lactam products. An exception to this trend was the interesting formation of quinolone **4**[9] via a tandem 6-*endo* cyclization-desulfonylation pathway (Eq. (2)).

Laser flash photolysis (LFP) studies of the radical precursors in Entries 5 and 6 of Table 1 demonstrated that the 5-*exo* radical cyclization reactions were quite fast. THF solutions of the precursors at ambient temperature were irradiated with 266 nm light from a Nd-YAG laser. Time-resolved UV-vis spectroscopy showed "instant" formation of the PhSe• radical (λ_{max} at 295 and 490 nm) as well as peaks we attribute to the products of the cyclization event. Specifically, peaks with λ_{max} at 315 nm and 334 nm were observed from the precursors in Entries 5 and 6, respectively, as expected for benzylic and diphenylalkyl radicals.[14] The "instant" formation of the products requires that the cyclization reactions had rate constants exceeding $2x10^8 s^{-1}$. Because aryl substitution on the ethenyl group results in increases of about 2 orders of magnitude in the rate constants for 5-*exo* radical cyclizations,[15] we conclude that the cyclizations of carbamoyl radicals from precursors such as **2** have rate constants exceeding $2x10^6 s^{-1}$ at ambient temperature, which is comparable in magnitude to those observed for alkoxy carbonyl cyclizations under similar conditions.[16] Furthermore, the rate constants for the 5-*exo* cyclizations of carbamoyl radicals are more than an order of magnitude larger than the rate constants for cyclizations of carbon-centered radical analogs.[17]

In conclusion, readily available N-substituted Se-phenylselenocarbamates are useful precursors for carbamoyl radicals in 5-*exo* cyclizations.

Acknowledgment. The authors wish to thank the National Science Foundation for their generous support of this research.

REFERENCES AND NOTES

1. (a) Chatgilialoglu, C.; Ferreri, C.; Lucarini, M. *Chem. Eur. J.* **1997**, *3*, 376. (b) Evans, P. A.; Roseman, J. D. *J. Org. Chem.* **1996**, *61*, 2252. (c) Crich, D.; Chen, C., Hwang, J. T.; *J. Am. Chem. Soc.* **1994**, *116*, 8937. (d) Boger, D. L.; Mathvink, R. J. *J. Org. Chem.* **1992**, *57*, 1429.

2. (a) Saicic, R. N.; Zard, S. Z. *J. Chem. Soc. Chem. Commun.* **1996**, 1631. (b) Bachi, M. D.; Bosch, E. *J. Org. Chem.* **1992**, *57*, 4696. (c) Bachi, M. D.; Bosch, E. *Tetrahedron Lett.*, **1986**, *27*, 641.
3. (a) Bachi, M. D.; Melman, A.; Barner, N. *J. Org. Chem.*, **1997**, *62*, 1896. (b) Bachi, M. D.; Balanov, A.; Barner, N. *Ibid.* **1994**, *59*, 7752.
4. (a) Pattenden, G.; Reynolds, S. J. *J. Chem. Soc. Perkin Trans 1* **1994**, 379. (b) Gill, G. B.; Pattenden, G.; Reynolds, S. J. *Ibid.* **1994**, 369. (c) Wender, P. A.; Singh, S. K. *Tetrahedron Lett.* **1990**, *31*, 2517. (d) Elad, D.; Rokach, J. *J. Org. Chem.* **1964**, *29*, 1855.
5. Barrett, A. G. M.; Kwon, H.; Wallace, E. M. *J. Chem. Soc. Chem. Commun.* **1993**, 1760.
6. N-alkyl substituted carbamoyl radicals are known to exist as a mixture of the respective E- and Z-conformers: Sutcliffe, R.; Ingold, K. U. *J. Am. Chem. Soc.* **1981**, *103*, 7686.
7. Curran has noted a temperature effect on the yields of atom-transfer cyclizations of α-amide radicals that is presumably a reflection of the rate of conformer interconversion: Curran, D. P.; Tamine, J. *J. Org. Chem.* **1991**, *56*, 2746.
8. The rate constant for rotation in an α-amide radical at room temperature is $\approx 10^5 s^{-1}$: Horner, J. H.; Musa, O. M.; Miranda, N.; Newcomb, M. unpublished results.
9. This compound exhibited spectral (^{1}H NMR, ^{13}C NMR, IR) and analytical (HRMS) data fully consistent with the assigned structure.
10. Typical experimental conditions; Method A: The Se-phenylselenocarbamate (0.01 M in toluene) was refluxed for 12 h in the presence of catalytic AIBN and $(TMS)_3SiH$ (1.5 equiv.). If starting material remained at this time, an additional 1 equiv. of $(TMS)_3SiH$ was added and heating continued. Method B: The Se-phenylselenocarbamate (0.01 M in toluene) was refluxed for 12-16 h with sun lamp irradiation in the presence of 0.3 equiv. of $(Bu_3Sn)_2$ and 2 equiv. of Bu_3SnH.
11. Acyl radicals are known to abstract hydrogen more slowly from $(TMS)_3SiH$ than from Bu_3SnH: Chatgilialoglu, C.; Lucarini, M. *Tetrahedron Lett.* **1995**, *36*, 1299.
12. The reactions in Entries 5 and 6 afforded little cyclized product with $(TMS)_3SiH$/AIBN, and $(Bu_3Sn)_2/Bu_3SnH$ afforded primarily decarbonylated products at higher concentrations: Bachi, M. D.; Balanov, A.; Bar-Ner, N.; Bosch, E.; Denenmark, D.; Mizhiritskii, M. *Pure & Appl. Chem.* **1993**, *65*, 595.
13. For radical cyclizations wherein the electronic nature of the N-substituent influences the course of reaction, see: Padwa, A.; Nimmesgarn, H.; Wong, G. S. K. *J. Org. Chem.* **1985**, *50*, 5620.
14. Chatgilialoglu, C. In *Handbook or Organic Photochemistry;* Scaiano, J. C., Ed.; CRC Press: Boca Raton, 1989; Vol. 2; pp. 3-11.
15. 5-*Exo* cyclizations of substrates with terminal diphenylethenyl acceptors are known to be approximately two orders of magnitude faster than cyclizations involving terminal alkenes: Newcomb, M.; Horner, J. H.; Filipkowski, M. A.; Ha, C.; Park, S. U. *J. Am. Chem. Soc.* **1995**, *117*, 3674.
16. Simakov, P. A.; Martinez, F. N.; Horner, J. H.; Newcomb, M. *J. Org. Chem.* **1998**, *63*, 1226.
17. Newcomb, M. *Tetrahedron* **1993**, *49*, 1151.