Asymmetric Intramolecular Selenoetherification and Selenolactonization using an Optically Active Diaryl Diselenide derived from D-Mannitol

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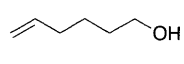
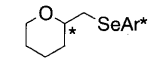
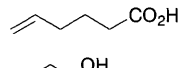
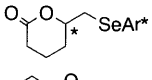
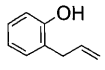
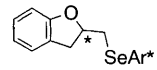
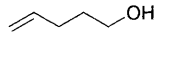
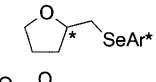
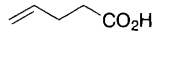
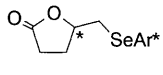
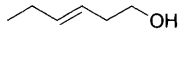
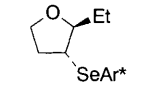
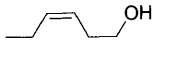
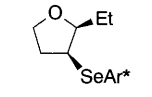
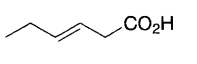
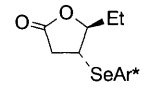
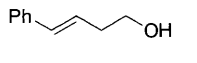
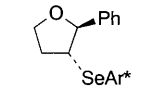
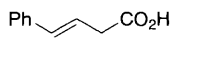
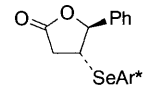
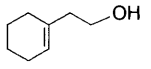
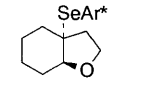
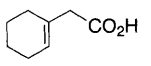
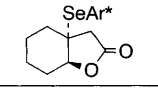
High asymmetric induction is observed in intramolecular selenoetherification and selenolactonization by employing the selenohexafluorophosphate of an optically active diaryl diselenide derived from D-mannitol.

Organoselenium compounds are frequently employed in organic synthetic chemistry to mediate functional group transformations, which are otherwise difficult to achieve.[1] Especially, the addition of electrophilic organoselenium reagents across carbon–carbon double bonds is of extreme importance in selective organic synthesis because it is not only stereospecific in many cases, but also applicable to a variety of nucleophiles.[2] For example, the intramolecular oxyselenenylation of unsaturated alcohols and carboxylic acids gives the corresponding selenoethers and selenolactones, respectively.[3] We recently reported the asymmetric methoxyselenenylation of simple alkenes using optically active selenocompounds such as selenobinaphthyls[4] and a chiral diaryl diselenide **1** having a chiral pyrrolidine ring with C_2 symmetry at the *ortho*-position of the selenium.[5] It was expected that the chirality of the pyrrolidine ring of **1** might be effectively transferred to the reaction site through the strong Se···N non-bonded interaction between the selenium and the pyrrolidine nitrogen.[5a,6] Herein we report the first application to asymmetric intramolecular oxyselenenylation such as selenoetherification of unsaturated alcohols and selenolactonization of unsaturated carboxylic acids using an optically active diaryl diselenide **1**, readily derived from D-mannitol.

The asymmetric intramolecular oxyselenenylation was carried out as follows (Scheme 1). To a dichloromethane solution (2 ml) of **1** (21 mg, 0.021 mmol), which was synthesized according to the previous procedure,[5] a 0.1 mol dm^{-3} tetrachloromethane solution of bromine (0.21 ml) was added

Table 1 Asymmetric intramolecular oxyselenenylation of various alkenes containing hydroxy or carboxy groups

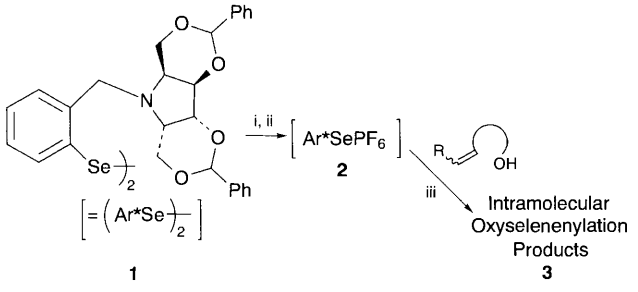
Entry		Product		Yield (%)[a]	D.e. (%)
1			**3a**	80	59
2			**3b**	90	39
3			**3c**	83	13
4			**3d**	100	22
5			**3e**	81	57
6			**3f**[b]	86	>98
7			**3g**[c]	71	56
8			**3h**[b]	90	>98
9			**3i**[b]	88	94
10			**3j**	87	92
11			**3k**[b]	62	13
12			**3l**[b]	73	77

[a] Isolated yield. [b] The stereochemistry of the major isomer was assumed to be the same as that in entry 10. [c] The stereochemistry of the major isomer is unknown.

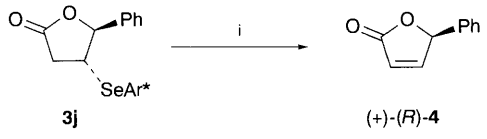
dropwise at −78 °C under nitrogen atmosphere. After 20 min stirring, a 0.32 mol dm^{-3} dichloromethane solution of silver hexafluorophosphate (150 μl, 0.048 mmol) was added. The resulting heterogeneous mixture of selenohexafluorophosphate **2** was stirred at −78 °C for 20 min and then cooled to −100 °C. Then a dichloromethane solution (1 ml) of the alkene substrate (0.33 mmol) was added at −100 °C. The resulting mixture was stirred for several hours from −100 °C to −40 °C. It was then quenched with aqueous sodium hydrogen carbonate solution and subjected to the usual extractive workup with dichloromethane. The residual oil obtained after evaporation of the solvent was purified by gel permeation chromatography to give the corresponding intramolecular oxyselenenylation product **3** in 62–100% yield.† The d.e.s of **3** determined by integration of ^1H NMR absorptions due to their diastereoisotopic protons are listed in Table 1.

First, we examined asymmetric reactions of various monosubstituted alkenes (entries 1–5). All reactions proceeded immediately at −100 °C and the chemical yields were fairly good. In entries 4 and 5, the corresponding five-membered product was exclusively obtained as a single product. In spite of difficulty in the diastereofacial stereoselective control of the chiral selenium reagent toward monosubstituted alkenes, moderate d.e.s were obtained in entries 1 and 5 (59%, **3a**; 57%, **3e**).

Encouraged by these results, we subsequently examined the diastereofacial selectivity of disubstituted alkenes (entries 6–10). Asymmetric intramolecular selenoetherification of (*E*)-hex-3-enol gave a much better d.e. than that of the corresponding (*Z*)-isomer (>98% **3f**; 56%, **3g**). This tendency for facial selectivity is in accordance with that of the asymmetric methoxyselenenylation with (*E*)- and (*Z*)-β-methylstyrene.[5b] When (*E*)-alk-3-enic acids were employed as a disubstituted alkene, the intramolecular oxyselenenylations proceeded with high diastereoselectivity to provide the corresponding selenolactones (>98% d.e., **3h**; 92% d.e., **3l**). We then examined the reaction of trisubstituted alkenes containing cyclohexene ring (entries 11, 12). Both reactions proceeded in reasonable chemical yields, especially with cyclohexenyl acetic acid, the corresponding selenolactone **3f** was obtained in 77% d.e. (entry 12).



Scheme 1 *Reagents and conditions*: i, Br_2, CCl_4; ii, $AgPF_6$, molecular sieves (4 Å), CH_2Cl_2, −78 °C; iii, −100 to −40 °C



Scheme 2 *Reagents and conditions*: i, H_2O_2, CH_2Cl_2, room temp. The absolute configurations of the major isomers are shown.

To date, we have established only the absolute stereochemistry of the major isomer of **3j** thus obtained by the sign of optical rotation[7] of its oxidative deselenenylation product **4**[4c] (Scheme 2). This tendency for facial selectivity of the selenium reagent toward a (*E*)-disubstituted alkene holds in the asymmetric methoxyselenenylation with (*E*)-β-methylstyrene.[5a] The absolute stereochemistry of major isomers for other products have not been determined, but they are assumed to be the same as that of **3j** for (*E*)-alkenes (Table 1).

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Footnote

† *Selected data* for **3e**: IR (neat) ν/cm^{-1} 2916, 2858, 1773, 1458, 1394, 1170, 1125, 760, 700; ^1H NMR ($CDCl_3$) δ 7.61–7.18 (m, 14 H), 5.50 (s, 2 H), 4.76 (d, *J* 16 Hz, 0.79 × 1 H), 4.73 (d, *J* 16 Hz, 0.21 × 1 H), 4.70–4.64 (m, 0.21 × 1 H), 4.62–4.57 (m. 0.79 × 1 H), 4.40 (d, *J* 2.3 Hz, 2 H), 4.11 (d, *J* 13 Hz, 2 H), 3.96 (dd, *J* 13, 2.4 Hz, 2 H), 3.98–3.94 (m, 1 H), 3.51 (s, 2 H), 3.36 (dd, *J* 13, 4.9 Hz, 0.21 × 1 H), 3.25 (dd, *J* 13, 4.9 Hz, 0.79 × 1 H), 3.01 (dd, *J* 13, 8.3 Hz, 0.79 × 1 H), 2.92 (dd, *J* 13, 8.3 Hz, 0.21 × 1 H), 2.52–2.28 (m, 3 H), 1.99–1.80 (m, 1 H); HRMS Found: *m/z* 607.1456. Calc. for $C_{32}H_{33}NO_6Se$, *M* 607.1471.

References

1 *Organoselenium Chemistry*, ed. D. Liotta, Wiley, London, 1987; *Selenium Reagents and Intermediates in Organic Synthesis*, ed. C. Paulmier, Pergamon, Oxford, 1986.

2 G. H. Schmid and D. G. Garratt, in *The Chemistry of Double-Bonded Functional Groups*, ed. S. Patai, Wiley, London, 1977, supp. A, part 2; D. G. Garratt and A. Kabo, *Can. J. Chem.*, 1980, **58**, 1030.

3 D. J. Clive, G. Chittattu, N. J. Curtis, W. A. Kiel and C. K. Wong, *J. Chem. Soc., Chem. Commun.*, 1977, 725; D. Goldsmith, D. Liotta, C. Lee and G. Zima, *Tetrahedron Lett.*, 1979, **20**, 4801; K. C. Nicolaou, S. P. Seitz, W. J. Sipio and J. F. Blount, *J. Am. Chem. Soc.*, 1979, **101**, 3884; K. C. Nicolaou, R. L. Magolda, W. J. Sipio, W. E. Barnette, Z. Lysenko and M. M. Joullie, *J. Am. Chem. Soc.*, 1980, **102**, 3784.

4 (*a*) S. Tomoda and M. Iwaoka, *Chem. Lett.*, 1988, 1895; (*b*) S. Tomoda, K. Fujita and M. Iwaoka, *J. Chem. Soc., Chem. Commun.*, 1990, 129; (*c*) S. Tomoda, K. Fujita and M. Iwaoka, Phosphorus Sulfur Silicon Relat. Elem., 1992, **67**, 125; (*d*) K. Fujita, K. Murata, M. Iwaoka and S. Tomoda, *Heteroatom Chem.*, 1995, in press.

5 (*a*) K. Fujita, M. Iwaoka and S. Tomoda, *Chem. Lett.*, 1994, 923; (*b*) K. Fujita, K. Murata, M. Iwaoka and S. Tomoda, *Tetrahedron Lett.*, submitted.

6 M. Iwaoka and S. Tomoda, *J. Am. Chem. Soc.*, 1994, **116**, 2557; M. Iwaoka and S. Tomoda, Phosphorus Sulfur Silicon Relat. Elem., 1992, **67**, 125.

7 A. Albinati, P. Bravo, F. Ganazzoli, G. Resnati and F. Viani, *J. Chem. Soc., Perkin Trans. 1*, 1986, 1405.