Synthesis and Absolute Configuration of Optically Active Selenoxides.[1] X-Ray Molecular Structure of (−)$_{Se}$-4-Menthyloxycarbonylphenyl 2,4,6-Tri-isopropyl-phenyl Selenoxide

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Enantiomerically pure, stable 4-(methoxycarbonyl)phenyl 2,4,6-tri-isopropylphenyl selenoxide (−)-(3) was isolated by fractional recrystallization of diastereoisomeric 4-[(−)-menthyloxycarbonyl]-phenyl 2,4,6-tri-isopropylphenyl selenoxide *dia.*-(1) followed by removal of the chiral source. The absolute configuration around the selenium atom was determined by X-ray crystallographic analysis of diastereomerically pure selenoxide (−)$_{Se}$-(1).

Very little work on optically active selenoxides has recently been reported except for a study on diastereoisomeric isomers of steroidal systems.[2] The difficulty of optical resolution of the racemic selenoxides is attributed to their readily occurring racemization through an achiral hydrate [RSe(OH)$_2$R'].[3,4] Recently several enantiomeric selenoxides were prepared;[4—10] however, their optical purities (o.p.) were low, or it was found that racemization around the selenium atom occurred easily. We now report the synthesis of enantiomerically pure selenoxides by fractional recrystallization of diastereoisomeric selenoxides followed by removal of the chiral source. These optically active selenoxides were found to be stable towards racemization in air on protection of the seleninyl moiety with bulky substituents. The absolute configuration of the optically active selenoxides described is based on an X-ray crystallographic analysis and their c.d. spectra.

Results and Discussion

Optically pure diastereoisomeric selenoxide (−)$_{Se}$-(1) was synthesized by fractional recrystallization of diastereoisomeric 4-[(−)-menthyloxycarbonyl]phenyl 2,4,6-tri-isopropylphenyl selenoxide *dia.*-(1) ([α]$_D$ −30.5°, CHCl$_3$). The crystals which were obtained after five recrystallizations from methanol had negative rotation ([α]$_D$ −99.0°, CHCl$_3$).[11] Optical purity of the crystals (−)$_{Se}$-(1) was determined to be 100% by h.p.l.c. Optically active (+)$_{Se}$-(1) was also obtained from the mother liquor with 75% diastereoisomeric excess (d.e.) (Table 1).
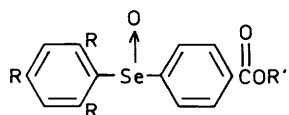
(1) R = Pr^i, R' = (−)-menthyl
(2) R = Bu^t, R' = (−)-menthyl
(3) R = Pr^i, R' = Me
(4) R = Bu^t, R' = Me

4-[(−)-Menthyloxycarbonyl]phenyl 2,4,6-tri-t-butylphenyl selenoxide *dia.*-(2) was also subjected to optical resolution by fractional recrystallization. D.e. of the crystals ([α]$_D$ −24.0°, CHCl$_3$) obtained by repeated recrystallization from methanol was ∼0% by measurement of the ^{77}Se n.m.r. spectrum,[13] and the optical rotation was found to be attributable to the

Table 1. Optical resolution of *dia.*-(1)

	(−)$_{Se}$ crystal	(+)$_{Se}$ from mother liquor
Optical purity^a (%)	100	75.3
[α]$_D$ (CHCl$_3$)^b (°)	−99.0	+17.7
M.p. (°C)	186.5—187.5	147—151

^{a} Optical purities were determined by h.p.l.c. using an optically active column.[12] ^{b} Optical rotations were taken in chloroform at 26 °C [(−)$_{Se}$-(1)] and 19 °C [(+)$_{Se}$-(1)].

Table 2. Optical resolution of *dia.*-(2)

	Crystal	(−)$_{Se}$ from mother liquor
Optical purity^a (%)	∼0	31.1
[α]$_D$ (CHCl$_3$)^b (°)	−24.0	−67.6
M.p. (°C)	145—146	viscous liquid

^{a} Optical purities were determined by ^{77}Se n.m.r. spectroscopy.[13] ^{b} Optical rotations were taken in chloroform at 25 °C.

(−)-menthyl moiety. In this case, the optically active isomer was obtained from the mother liquor of the four recrystallizations from each mother liquor. This optically active isomer (−)$_{Se}$-(2) had negative rotation ([α]$_D$ −67.6°, CHCl$_3$) and the d.e. was 31% (Table 2). However, (+)$_{Se}$-(2) could not be obtained from any fractions. Resolution to give optically active (−)$_{Se}$-(2) may be attributed to asymmetric induction during the oxidation process from the corresponding selenide to the selenoxide (2) because the selenoxide (2) from oxidation of the corresponding selenide showed an optical rotation of −34.7° (CH$_2$Cl$_2$). D.e. of *dia.*-(2) was determined to be 7.6% although the mechanistic aspects are not clear at the present time.

These optically active selenoxides thus obtained were diastereoisomerically active selenoxides containing two chiral moieties. We attempted their conversion into the enantiomeric selenoxides by removal of the (−)-menthyl moiety. Transesterifications of (−)$_{Se}$-(1) and (+)$_{Se}$-(1) to the methyl esters were carried out in methanol in the presence of sodium methoxide at room temperature and with monitoring by h.p.l.c. The (−)-menthyl groups were completely displaced by methyl after 4 days. However, the optical purities of the resulting selenoxides (−)-(3) and (+)-(3) were decreased to 88 and 70%, respectively. The long reaction time must be the reason for the decline of the optical purities. In order to shorten the reaction time, the transesterification was attempted
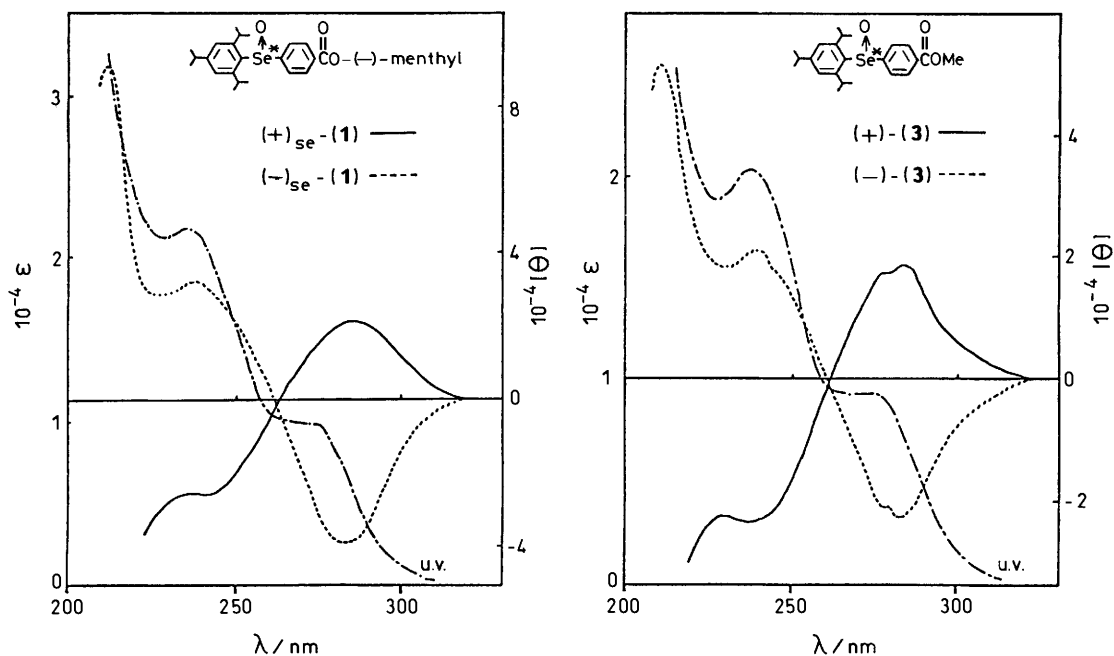
in aprotic polar solvents. Optically pure enantiomeric selenoxide (−)-(3) was finally obtained by transesterification of (−)$_{Se}$-(1) in N,N-dimethylformamide DMF) without

$$(-)_{Se}\text{-}(1) \xrightarrow{i} (-)\text{-}(3)$$
$$\text{(o.p. 100\%)} \quad \text{(o.p. 88\%)}$$

$$(+)_{Se}\text{-}(1) \xrightarrow{i} (+)\text{-}(3)$$
$$\text{(o.p. 75\%)} \quad \text{(o.p. 70\%)}$$

$$(-)_{Se}\text{-}(1) \xrightarrow{ii} (-)\text{-}(3)$$
$$\text{(o.p. 100\%)} \quad \text{(o.p. 100\%)}$$
$$[\alpha]_D -84.3°(CHCl_3)$$

Scheme 1. *Reagents and conditions:* i, NaOMe, MeOH, room temp., 4 days; ii, NaOMe, MeOH–DMF (1:9), room temp., 25 min

racemization within 25 min at room temperature (Scheme 1). The optical purity of (−)-(3) was determined to be 100% by h.p.l.c. using an optically active column.[12] This compound is the first example of a stable, enantiomerically pure selenoxide.

On the other hand, transesterification of (−)$_{Se}$-(2) showed an unexpected result in the work-up step. Transesterification of (−)$_{Se}$-(2) (o.p. 31%) with sodium methoxide in methanol gave a reaction mixture with 29% o.p. When the reaction mixture was washed with hexane, the resulting solid showed only 13% o.p. Surprisingly, the hexane mother liquor contained the selenoxide of high o.p. (80%) (Scheme 2). The relationship

$$(-)_{Se}\text{-}(2) \xrightarrow{i} (-)\text{-}(4)$$
$$\text{(o.p. 31\%)} \qquad\qquad \text{(o.p. 29\%)}$$

removal of (−)-menthol
(30 °C/10^{-5} mmHg)

hexane -   hexane -
soluble   insoluble
(−)-isomer   (−)-isomer
(o.p. 80%)   (o.p. 13%)

alumina
p.l.c.

(o.p. 80%)
[α]$_D$−143° (CHCl$_3$)

Scheme 2. *Reagent and conditions:* i, NaOMe, MeOH, room temp., 50 h

of the solubility between two enantiomers corresponds to that of the diastereoisomers observed in the recrystallization of *dia.*-(2) described above; namely, optically active crystals of the selenoxides (2) and (4) are more soluble in hexane or methanol than are the racemic crystals.

The absolute configuration of the optically active selenoxide (−)$_{Se}$-(1) was determined by X-ray crystallographic analysis. The molecular structure of the optically pure (−)$_{Se}$-(1) is shown in Figure 1. Positional parameters are presented in Table 3. Bond distances and bond angles are given in Table 4. The steric configuration around the selenium atom of (−)$_{Se}$-(1) was thus determined to be S. Since there is no inversion of configuration around the selenium atom during the transesterification from

Table 3. Positional parameters (× 10⁴)

Atom	x	y	z
Se(1)	2 295(1)	−1 983(1)	1 162(2)
O(1)	2 338(4)	−1 850(7)	−1 514(11)
O(2)	3 783(4)	2 228(5)	2 983(11)
O(3)	3 353(5)	2 003(5)	6 283(13)
C(1)	1 186(4)	−1 953(10)	1 780(13)
C(2)	667(6)	−1 334(7)	783(16)
C(3)	−149(6)	−1 424(8)	1 154(17)
C(4)	−414(5)	−2 094(13)	2 469(17)
C(5)	118(6)	−2 738(8)	3 415(16)
C(6)	930(6)	−2 674(7)	3 143(14)
C(7)	934(6)	−556(7)	−601(18)
C(8)	753(8)	356(8)	497(21)
C(9)	554(8)	−607(9)	−2 946(18)
C(10)	−1 302(6)	−2 262(9)	2 825(20)
C(11)	−1 532(9)	−1 554(15)	4 450(36)
C(12)	−1 776(7)	−2 296(12)	809(26)
C(13)	1 510(7)	−3 329(7)	4 288(18)
C(14)	1 645(8)	−4 098(8)	2 806(21)
C(15)	1 198(9)	−3 684(9)	6 479(18)
C(16)	2 599(6)	−779(7)	2 286(16)
C(17)	3 055(6)	−278(7)	832(17)
C(18)	3 310(6)	556(7)	1 545(17)
C(19)	3 142(5)	856(7)	3 626(16)
C(20)	2 717(6)	317(7)	5 063(17)
C(21)	2 441(6)	−518(7)	4 395(15)
C(22)	3 442(6)	1 762(7)	4 512(16)
C(23)	4 093(6)	3 098(10)	3 530(16)
C(24)	4 979(5)	3 083(11)	3 333(15)
C(25)	5 290(8)	4 078(9)	3 658(25)
C(26)	4 918(8)	4 655(8)	1 869(23)
C(27)	4 024(8)	4 683(9)	1 920(24)
C(28)	3 692(8)	3 717(8)	1 748(22)
C(29)	5 367(8)	2 390(10)	4 854(19)
C(30)	6 187(8)	2 155(11)	4 218(26)
C(31)	5 365(9)	2 659(9)	7 369(19)
C(32)	3 633(10)	5 241(11)	102(28)

Figure 1. Molecular conformation observed in the crystal of (−)$_{Se}$-(1)

(−)$_{Se}$-(1) to (−)-(3), the absolute configuration of (−)-(3) is concluded also to be S. The observation of negative Cotton effects at the same wavelength region (284 nm) in the c.d. spectra of (−)$_{Se}$-(1) and (−)-(3) also supports this conclusion (Figure 2). The opposite optical isomers (+)$_{Se}$-(1) and (+)-(3) which show a positive Cotton effect at 284 and 283 nm, respectively, are determined to be R. The absolute configurations of the other selenoxides (−)$_{Se}$-(2) and (−)-(4) were estimated from the c.d.

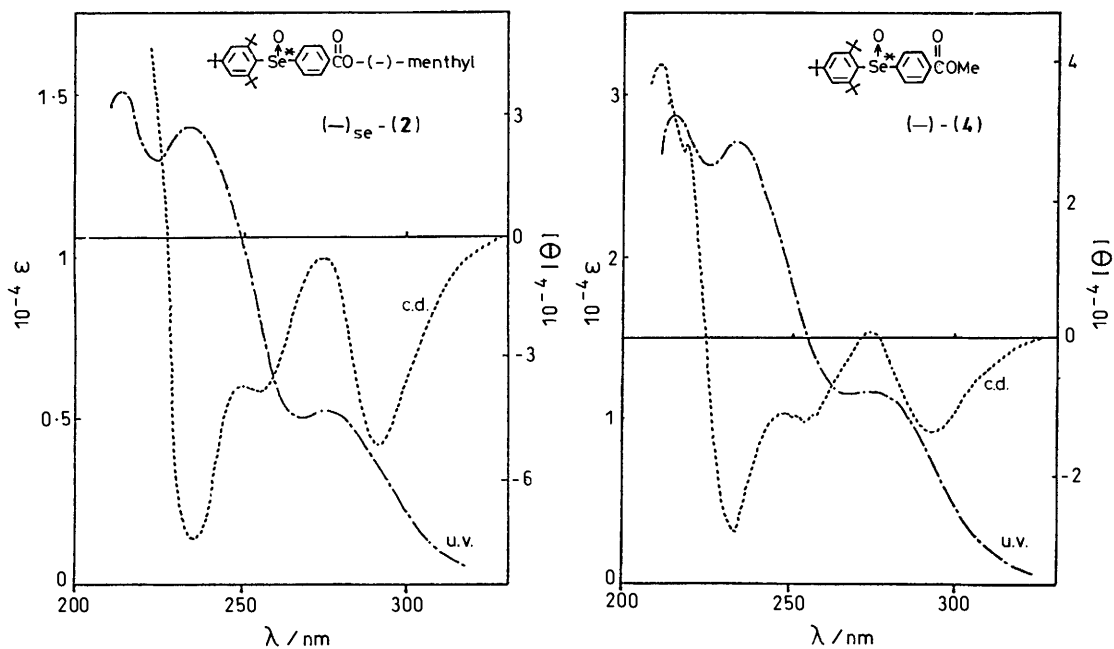**Figure 2.** C.d. and u.v. spectra of optically active selenoxides (1) and (3)

Figure 3. C.d. and u.v. spectra of optically active selenoxides (2) and (4)

spectra. The c.d. spectra of diastereoisomeric $(-)_{Se}$-(2) and enantiomeric $(-)$-(4) also show negative Cotton effects in this region (292 nm) (Figure 3). Therefore, by comparison of optical rotation and c.d. spectra between tri-isopropylphenyl-substituted selenoxides $(-)_{Se}$-(S)-(1) and $(-)$-(S)-(3), and tri-t-butylphenyl derivatives $(-)_{Se}$-(2) and $(-)$-(4), the absolute configuration of $(-)_{Se}$-(2) and $(-)$-(4) is estimated also to be S (Figure 4).

In conclusion, enantiomerically pure, stable (even in air at room temperature) selenoxides were isolated for the first time. The absolute configuration around the selenium atom of an optically active selenoxide was also determined for the first time by X-ray diffraction of a diastereoisomerically pure selenoxide.

$(S) - (-)$

R = Pr^i, Bu^t
R' = (—) – menthyl, Me
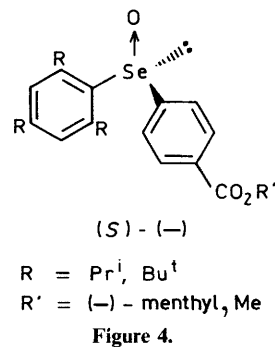
Figure 4.

Table 4. Bond lengths (Å) and angles (°)

Se(1)–O(1)	1.662(7)	C(13)–C(14)	1.486(17)
Se(1)–C(1)	1.945(8)	C(13)–C(15)	1.565(17)
Se(1)–C(16)	1.976(10)	C(16)–C(17)	1.423(14)
O(2)–C(22)	1.324(13)	C(16)–C(21)	1.393(14)
O(2)–C(23)	1.428(16)	C(17)–C(18)	1.376(14)
O(3)–C(22)	1.164(13)	C(18)–C(19)	1.398(14)
C(1)–C(2)	1.396(15)	C(19)–C(20)	1.418(14)
C(1)–C(6)	1.440(16)	C(19)–C(22)	1.530(15)
C(2)–C(3)	1.426(15)	C(20)–C(21)	1.381(15)
C(2)–C(7)	1.518(15)	C(23)–C(24)	1.521(13)
C(3)–C(4)	1.374(19)	C(23)–C(28)	1.562(17)
C(4)–C(5)	1.421(18)	C(24)–C(25)	1.579(21)
C(4)–C(10)	1.558(14)	C(24)–C(29)	1.519(19)
C(5)–C(6)	1.405(14)	C(25)–C(26)	1.508(19)
C(6)–C(13)	1.532(15)	C(26)–C(27)	1.525(20)
C(7)–C(8)	1.551(17)	C(27)–C(28)	1.543(18)
C(7)–C(9)	1.552(16)	C(27)–C(32)	1.518(22)
C(10)–C(11)	1.515(25)	C(29)–C(30)	1.509(20)
C(10)–C(12)	1.445(19)	C(29)–C(31)	1.597(17)
O(1)–Se(1)–C(1)	106.5(3)	Se(1)–C(16)–C(21)	121.2(8)
O(1)–Se(1)–C(16)	102.4(5)	C(17)–C(16)–C(21)	125.2(9)
C(1)–Se(1)–C(16)	98.7(5)	C(16)–C(17)–C(18)	116.3(9)
C(22)–O(2)–C(23)	118.3(8)	C(17)–C(18)–C(19)	120.2(10)
Se(1)–C(1)–C(2)	121.9(8)	C(18)–C(19)–C(20)	121.7(9)
Se(1)–C(1)–C(6)	115.0(8)	C(18)–C(19)–C(22)	121.7(9)
C(2)–C(1)–C(6)	122.8(8)	C(20)–C(19)–C(22)	116.5(9)
C(1)–C(2)–C(3)	118.0(9)	C(19)–C(20)–C(21)	119.9(9)
C(1)–C(2)–C(7)	123.1(9)	C(16)–C(21)–C(20)	116.6(9)
C(3)–C(2)–C(7)	118.9(9)	O(2)–C(22)–O(3)	125.9(10)
C(2)–C(3)–C(4)	120.9(10)	O(2)–C(22)–C(19)	110.9(8)
C(3)–C(4)–C(5)	120.5(9)	O(3)–C(22)–C(19)	123.1(10)
C(3)–C(4)–C(10)	123.3(11)	O(2)–C(23)–C(24)	109.0(11)
C(5)–C(4)–C(10)	116.0(12)	O(2)–C(23)–C(28)	103.0(8)
C(4)–C(5)–C(6)	121.1(10)	C(24)–C(23)–C(28)	110.6(10)
C(1)–C(6)–C(5)	116.7(9)	C(23)–C(24)–C(25)	107.8(12)
C(1)–C(6)–C(13)	122.1(9)	C(23)–C(24)–C(29)	111.3(11)
C(5)–C(6)–C(13)	121.2(9)	C(25)–C(24)–C(29)	115.0(9)
C(2)–C(7)–C(8)	110.3(9)	C(24)–C(25)–C(26)	108.3(10)
C(2)–C(7)–C(9)	111.1(9)	C(25)–C(26)–C(27)	112.5(12)
C(8)–C(7)–C(9)	111.4(9)	C(26)–C(27)–C(28)	109.7(11)
C(4)–C(10)–C(11)	105.5(11)	C(26)–C(27)–C(32)	113.6(12)
C(4)–C(10)–C(12)	112.9(10)	C(28)–C(27)–C(32)	108.1(12)
C(11)–C(10)–C(12)	116.0(12)	C(23)–C(28)–C(27)	110.7(11)
C(6)–C(13)–C(14)	108.8(9)	C(24)–C(29)–C(30)	112.1(11)
C(6)–C(13)–C(15)	111.7(10)	C(24)–C(29)–C(31)	113.8(11)
C(14)–C(13)–C(15)	109.8(10)	C(30)–C(29)–C(31)	110.9(11)
Se(1)–C(16)–C(17)	113.3(7)		

Experimental

M.p.s were determined on a Yamato MP-21 and were uncorrected. I.r. spectra were recorded on a Hitachi 260-10 spectrometer, and ^{1}H n.m.r. spectra with SiMe$_4$ as internal standard were taken on a JEOL JNM-PMX 60$_{SI}$. Mass spectra were measured on a JEOL JMS-DX-300 mass spectrometer. The optical rotations were measured on a JASCO DIP-140 digital polarimeter, and c.d. spectra were recorded on a JASCO J-40A spectrometer. Silica gel t.l.c. and column chromatography were performed with Merck Kieselgel 60F$_{254}$ and Wakogel C-200, respectively. Alumina preparative t.l.c. (p.l.c.) was performed with Merck Aluminiumoxid 150F$_{254}$ (Typ T). Organic solvents were purified and dried by the usual procedures. X-Ray data collection was carried out on a Rigaku RASA-5 four-circle diffractometer and the computations were performed on a FACOM 200 computer.

Optically Active 4-[(−)-*Menthyloxycarbonyl*)*phenyl* 2,4,6-*Tri-isopropylphenyl Selenoxides* (−)$_{Se}$- *and* (+)$_{Se}$-(**1**).—A mix-

ture of 2,4,6-tri-isopropylbenzeneselenol (1.80 g, 6.36 mmol), *p*-iodobenzoic acid (1.57 g, 6.36 mmol), sodium hydroxide (1.30 g), copper powder (400 mg), and water (30 ml) was refluxed overnight.[14] The product was extracted with ether after acidification with hydrochloric acid. Purification by silica gel column chromatography gave 4-carboxyphenyl 2,4,6-tri-isopropylphenyl selenide (**5**) in 47% yield; m.p. 219—220 °C; $v_{max.}$(KBr) 1 675 cm^{-1} (C=O); *m/z* 404 (*M*$^+$) (^{80}Se).

The carboxylic acid (**5**) (4.80 g, 11.9 mmol) and thionyl chloride (12 g) were heated at 60 °C for 2 h. After removal of excess thionyl chloride under reduced pressure, an excess of (−)-menthol (4.8 g) and pyridine (1.6 g) in benzene (50 ml) was added to the resulting acid chloride and the mixture was refluxed for 3 h. Water was added to the reaction mixture, and the organic layer was purified by silica gel chromatography. Further purification by recrystallization from methanol gave 4-[(−)-menthyloxycarbonyl]phenyl 2,4,6-tri-isopropylphenyl selenide (**6**) in 84% yield; m.p. 120—121 °C; $[\alpha]_D^{22} -30.8°$ (*c* 1.16 in CHCl$_3$); $v_{max.}$(KBr) 1 710 cm^{-1} (C=O); *m/z* 542 (*M*$^+$) (^{80}Se).

Finally, diastereoisomeric 4-[(−)-menthyloxycarbonyl]-phenyl 2,4,6-tri-isopropylphenyl selenoxide *dia.*-(**1**) was obtained by oxidation of the selenide (**6**) in 91% yield according to the literature;[6] m.p. 149—150.5 °C; $[\alpha]_D^9 -30.5°$ (*c* 1.00 in CHCl$_3$).

Fractional recrystallization of *dia.*-(**1**) was carried out at room temperature or in a freezer from methanol. Optically pure diastereoisomeric selenoxide (−)$_{Se}$-(**1**) (1.00 g) was obtained after five recrystallizations of *dia.*-(**1**) (7.30 g); m.p. 186.5—187.5 °C; $[\alpha]_D^{26} -99.0°$ (*c* 1.25 in CHCl$_3$); c.d. (MeOH) 284 ([θ] −3.88 × 10^4), 239 ([θ] +3.12 × 10^4), and 211 nm ([θ] +9.20 × 10^4); $\lambda_{max.}$(MeOH) 275 (ε 1.03 × 10^4), 240 (2.24 × 10^4), and 215 nm (3.20 × 10^4); $v_{max.}$(KBr) 820 (Se=O) and 1 710 cm^{-1} (C=O); δ (CDCl$_3$) 0.92, 1.24, 1.30 (18 H, each d, *J* 6.6 Hz, 3 × CH*Me*$_2$), 0.6—2.2 [18 H, m, (−)-menthyl except *O*-methine], 2.89 (1 H, hep., *J* 6.6 Hz, *p*-C*H*Me$_2$), 3.73 (2 H, hep., *J* 6.6 Hz, 2 × *o*-C*H*Me$_2$), 4.93 (1 H, dt, *J* 4.2, 9.9 Hz, *O*-methine), 7.03 (2 H, s, C$_6$*H*$_2$Pr$^i_3$), and 7.61 and 8.07 (4 H, ABq, *J* 8.4 Hz, ArH); *m/z* 558 (^{80}Se) [Found: *m/z*, 542.2661 (^{80}Se) (*M* − *O*). Calc. for C$_{32}$H$_{46}$O$_2$^{80}Se: *m/z*, 542.2662].

The diastereoisomer (+)$_{Se}$-(**1**) (1.45 g) was obtained from the above mother liquor from the first recrystallization. D.e. was 75.3% by h.p.l.c. analysis using an optically active column.[12] This d.e. could not be further increased in spite of repeated recrystallizations; m.p. 147—151 °C; $[\alpha]_D^9 +17.7°$ (*c* 1.29 in CHCl$_3$); c.d. (MeOH) 284 ([θ] +2.19 × 10^4), 240 ([θ] − 2.67 × 10^4), and 210 nm ([θ] −8.34 × 10^4); $\lambda_{max.}$(MeOH) 275 (ε 9.92 × 10^3), 235 (2.19 × 10^4), 210 nm (3.20 × 10^4); $v_{max.}$(KBr) 815 (Se=O) and 1 710 cm^{-1} (C=O); δ (CDCl$_3$) 0.90, 1.22, 1.28 (18 H, d, *J* 6.6 Hz, 3 × CH*Me*$_2$), 0.6—2.3 [18 H, m, (−)-menthyl except *O*-methine], 2.88 (1 H, hep., *J* 6.6 Hz, *p*-C*H*Me$_2$), 3.72 (2 H, hep., *J* 6.6 Hz, 2 × *o*-C*H*Me$_2$), 4.93 (1 H, dt, *J* 4.2, 9.9 Hz, *O*-methine), 7.02 (2 H, s, C$_6$*H*$_2$Pr$^i_3$), and 7.60 and 8.05 (4 H, ABq, *J* 8.4 Hz, ArH).

Optically Active 4-[(−)-*Menthyloxycarbonyl*]*phenyl* 2,4,6-*Tri-t-butylphenyl Selenoxide* (−)$_{Se}$-(**2**).—To a solution of 2,4,6-tri-t-butylphenyl-lithium in tetrahydrofuran (THF) (30 ml) prepared from 1-bromo-2,4,6-tri-t-butylbenzene (1.35 g, 4.00 mmol) and 1.54M butyl-lithium in hexane (3.90 ml, 6.00 mmol) at −60 °C was added dropwise a solution (10 ml) of ethyl *p*-selenocyanatobenzoate[15] (1.01 g, 6.00 mmol) in THF (10 ml) which was prepared from *p*-ethoxycarbonylbenzenediazonium chloride and potassium selenocyanate. The mixture was allowed to warm up to room temperature and the organic product was extracted with chloroform after addition of water (100 ml). Purification by silica gel column chromatography gave 4-(ethoxycarbonyl)phenyl 2,4,6-tri-t-butylphenyl selenide

(7) in 60% yield; m.p. 121—122 °C (from EtOH); $v_{max.}$(KBr) 1 705 cm^{-1} (C=O); m/z 474 (M^+) (^{80}Se).

Hydrolysis of this ester (7) was carried out with potassium hydroxide in methanol–water (2:1) (60 ml) to give 4-carboxyphenyl 2,4,6-tri-t-butylphenyl selenide (8) in quantitative yield; m.p. 247—250 °C (from EtOH); $v_{max.}$(KBr) 1 680 cm^{-1} (C=O); m/z 446 (M^+) (^{80}Se).

Esterification of the carboxylic acid (8) (5.00 g, 11.2 mmol) in a similar way to that of tri-isopropyl derivative (5) gave 4-[(−)-menthyloxycarbonyl]phenyl 2,4,6-tri-t-butylphenyl selenide (9) in 74% yield; m.p. 151—151.5 °C (from MeOH); $[\alpha]_D^{30}$ −27.0° (c 1.02 in CHCl$_3$); $v_{max.}$(KBr) 1 705 cm^{-1} (C=O); m/z 584 (M^+) (^{80}Se).

Diastereoisomeric selenoxide $dia.$-(2) was prepared by oxidation of the selenide (9) (2.25 g, 385 mmol) with t-butyl hypochlorite–pyridine–methanol.[6] Purification by silica gel chromatography gave the corresponding selenoxide $dia.$-(2) in 90% yield; m.p. 145—146 °C; $[\alpha]_D^{27}$ −34.7° (c 1.28 in CH$_2$Cl$_2$). Slightly asymmetric induction was observed in the case of oxidation of compound (9) and d.e. was determined to be 7.6%.

Fractional recrystallization of $dia.$-(2) (15.3 g) was repeated from methanol. (−)$_{Se}$-4-[(−)-Menthyloxycarbonyl]phenyl 2,4,6-tri-t-butylphenyl selenoxide (−)$_{Se}$-(2) (3.03 g) was obtained from the mother liquor of the four recrystallizations from each mother liquor. D.e. was determined to be 31.1%, which was estimated by measurement of the ^{77}Se n.m.r. spectrum[13] after purification by alumina p.l.c.; the product was a viscous oil; $[\alpha]_D^{25}$ −67.6° (c 1.61 in CHCl$_3$); c.d. (MeOH) 292 ([θ] −5.09 × 10^3), 255 ([θ] −3.80 × 10^3), and 235 nm ([θ] −7.40 × 10^3); $\lambda_{max.}$(MeOH) 275 (ε 5.13 × 10^3), 233 (1.40 × 10^4), and 213 nm (1.51 × 10^4); $v_{max.}$(neat) 830 (Se=O) and 1 710 cm^{-1} (C=O); δ(CDCl$_3$) 0.6—2.4 [(18 H, m, (−)-menthyl except O-methine), 1.37 (9 H, s, p-Bu^t], 1.48 (18 H, s, 2 × o-Bu^t), 4.89 (1 H, dt, J 5.6, 10.0 Hz, O-methine), 7.52 (2 H, s, C$_6$$H_2Bu^t_3$), and 7.01 and 7.91 (4 H, ABq, J 8.0 Hz, ArH); m/z 600 (M^+) (^{80}Se) [Found: m/z 584.3182 (^{80}Se) (M − O). Calc. for C$_{35}$H$_{52}$O$_2$^{80}Se: m/z 584.3133].

Transesterification of Diastereoisomeric Selenoxides to Enantiomeric Selenoxides.—Typical procedure of the transesterification in DMF–MeOH will be described. To a solution of optically active diastereoisomeric selenoxide (0.2 mmol) in DMF–MeOH (9:1) (100 ml) was added a solution of 28% sodium methoxide–methanol (1.0 ml). The mixture was stirred at room temperature until transesterification was complete. The reaction mixture was poured into water and the selenoxide was extracted with ether. The optically active selenoxide was purified by alumina p.l.c. after evaporation of (−)-menthol under reduced pressure (10^{-3}—10^{-4} mmHg). Thus were prepared (−)-4-(*methoxycarbonyl)phenyl* 2,4,6-*tri-isopropyl-phenyl selenoxide* (−)-(3), yield 66%; optical purity 100%; m.p. 206—207 °C; $[\alpha]_D^{24}$ −84.3° (c 1.39 in CHCl$_3$); c.d. (MeOH) 284 ([θ] −2.27 × 10^4), 240 ([θ] +2.11 × 10^4), and 210 nm ([θ] +5.24 × 10^4); $\lambda_{max.}$(MeOH) 275 (ε 9.28 × 10^3), 237 (2.03 × 10^4), and 214 nm (2.27 × 10^4); $v_{max.}$(KBr) 820 (Se=O) and 1 720 cm^{-1} (C=O); δ(CDCl$_3$) 0.92, 1.24, 1.30 (18 H, d, J 6.6 Hz, 3 × CHMe$_2$), 2.91 (1 H, hep., J 6.6 Hz, p-CHMe$_2$), 3.73 (2 H, hep., J 6.6 Hz, 2 × o-CHMe$_2$), 3.91 (3 H, s, OMe), 7.06 (2 H, s, C$_6$$H_2Pr^i_3$), and 7.65 and 8.10 (4 H, ABq, J 7.2 Hz, ArH); [Found: m/z 434.1390 (^{80}Se). C$_{23}$H$_{30}$O$_3$^{80}Se: m/z 434.1359]; and (+)-4-(*methoxycarbonyl)phenyl* 2,4,6-*tri-isopropylphenyl selenoxide* (+)-(3), yield 71%; optical purity 70%; m.p. 204—205.5 °C; $[\alpha]_D^{20}$ +66.9° (c 1.33 in CHCl$_3$); c.d. (MeOH) 283 ([θ] +1.84 × 10^4), 239 ([θ] −2.51 × 10^4), and 211 nm ([θ] −6.48 × 10^4). The u.v., i.r., and ^{1}H n.m.r. spectra were almost the same as those for (−)-(3).

(−)-4-(*Methoxycarbonyl)phenyl* 2,4,6-*tri-t-butylphenyl selen-oxide* (−)-(4), yield 13%; optical purity 80%; m.p. 126—

127.5 °C; $[\alpha]_D^{27}$ −143° (c 1.02 in CHCl$_3$); c.d. (MeOH) 292 ([θ] −1.38 × 10^4), 275 ([θ] +4.14 × 10^2), 254 ([θ] −1.24 × 10^4), and 234 nm ([θ] −2.76 × 10^4); $\lambda_{max.}$(MeOH) 275 (ε 1.17 × 10^4), 233 (2.72 × 10^4), and 214 nm (2.89 × 10^4); $v_{max.}$(KBr) 840 (Se=O) and 1 725 cm^{-1} (C=O); δ(CDCl$_3$) 1.34 (9 H, s, p-Bu^t), 1.44 (18 H, s, 2 × o-Bu^t), 3.84 (3 H, s, OMe), 6.94 and 7.86 (4 H, ABq, J 8.2 Hz, C$_6$H$_4$CO$_2$R), and 7.46 (2 H, s, ArH); m/z 476 (M^+) (^{80}Se) [Found: m/z 460.1916 (^{80}Se) (M − O). C$_{26}$H$_{36}$-O$_2$^{80}Se requires m/z 460.1880].

Crystal Data for Compound (−)$_{Se}$-(1).—C$_{32}$H$_{46}$O$_3$Se, M = 557.7. Monoclinic, a = 17.029(2), b = 14.848(2), c = 6.148(1) Å, β = 92.91(1)°, V = 1 552.2(5) Å^3, space group $P2_1$, Z = 2, D_x = 1.19 g cm^{-3}. Colourless rods. Crystal dimensions: 0.1 × 0.2 × 0.7 mm, μ(Mo-K_α) = 12.2 cm^{-1}. $F(000)$ = 592. T = 297 K.

Data Collection and Processing.—A Rigaku RASA-5 four-circle diffractometer with graphite-monochromated Mo-K_α radiation (0.7107 Å) was used. The unit-cell parameters were determined from 20 reflections with 22° < 2θ < 31°. Intensity data with 2θ < 55° ($-22 \leqslant h \leqslant 22$, $-19 \leqslant k \leqslant 19$, $0 \leqslant l \leqslant 7$) were collected with the 2θ–ω-scan technique (scan speed 6° min^{-1}) at 7 775 reflections. Three standard reflections measured every 100 reflections showed a 6.6% decay over the time of the entire data correction; a linear correction was made (statistical variation <3%). The intensities were corrected for Lorentz and polarization factors, but not for absorption.

Structure Analysis and Refinement.—The structure was solved by direct methods (MULTAN 71).[16] The refinement was carried out by the full-matrix least-squares method using the UNICS III program.[17] The absolute configuration was determined from the known absolute configuration of the (−)-menthyl group.* The final R was 0.080,† wR 0.089, weighting scheme $|\sigma^2(F_o) + 0.0009(F)^2|^{-1}$ for 3 612 independent reflections with $F_o > 3.0\sigma(F_o)$.‡ Atomic scattering factors were taken from International Tables for X-Ray Crystallography, vol. IV.[18] All the computations were carried out on a FACOM 200 computer at Tokyo Metropolitan University.§

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* The larger final R and ωR values (0.093 and 0.108) with f'' < 0 also supported this configuration.

† The quality of the crystal was not good. We tried unsuccessfully to make a single crystal of good quality.

‡ Max. shift/error = 0.17. Max. and min. height in final difference Fourier synthesis = 1.23 and −0.79 e Å^{-3}.

§ *Supplementary data* (see section 5.6.3 of Instructions for Authors, in the January issue). Thermal parameters have been deposited at the Cambridge Crystallographic Data Centre.

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