

1,2-Asymmetric induction in the radical addition of organotin hydrides to (–)-menthyl(*E*)-2,3-disubstituted propenoates¹

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Abstract

The results obtained in the free radical hydrostannation of (–)-menthyl(*E*)-2,3-diphenylpropenoate (**1**) with tri-*n*-butyl- and triphenyltin hydride, and of (–)-menthyl(*E*)-2-phenyl-2-butenolate (**7**) with trimethyltin hydride are reported. The absolute configuration of the new organotin adducts was determined by combining ¹H- and ¹³C-NMR data with chemical correlation. The additions took place in all cases following a *syn* stereochemistry that led to diastereomeric excesses ranging between 73 and 100%. The observed stereochemistry is explained, taking into account both the allylic strain and the hyperconjugation with β-trialkyltin substituent existing in the intermediate radicals. Full ¹H-, ¹³C- and ¹⁹Sn-NMR data are given. © 1998 Elsevier Science S.A. All rights reserved.

Keywords: 1,2-Asymmetric induction; Organotin hydrides; (–)-Menthyl(*E*)-2,3-disubstituted propenoates

1. Introduction

The addition of organotin hydrides to prochiral activated alkenes [1] has been included among the early examples of reactions that showed that 1,2-asymmetric induction was possible in radical reactions ([2]a). We have recently reported [3] a study on the addition of trimethyltin hydride to (–)-menthyl(*E*)-2,3-diphenylpropenoate, which confirmed the stereoselectivity of these free radical reactions and also enabled us to determine the absolute configuration of the organotin adducts.

In the present paper, we report the results obtained in the free radical additions of tri-*n*-butyl- and triphenyltin hydrides to (–)-menthyl(*E*)-2,3-diphenyl-

propenoate (**1**) and of trimethyltin hydride to (–)-menthyl(*E*)-2-phenyl-2-butenolate (**2**). These studies were carried out with the aim of determining whether both the olefin substituents and the type and size of the organic ligands attached to the tin atom have any effect on the stereoselectivity of these reactions.

2. Results and discussion

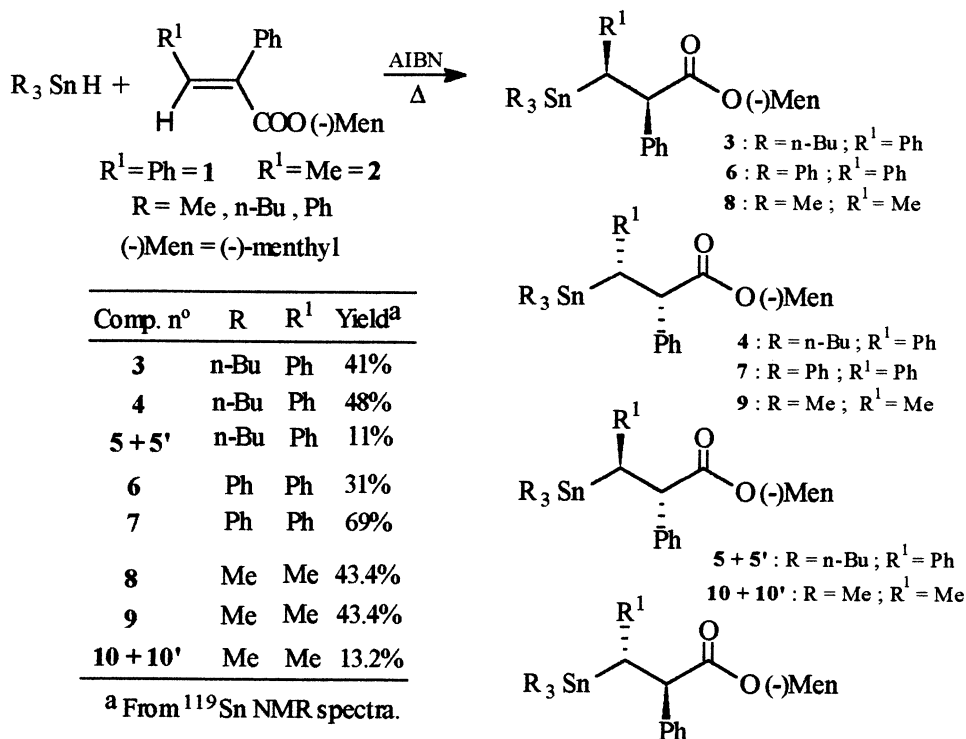
The addition under free radical conditions of tri-*n*-butyltin hydride to (–)-menthyl(*E*)-2,3-diphenylpropenoate (**1**) leads to a mixture of the four diastereoisomers expected, as shown in Scheme 1. The analysis by ¹¹⁹Sn-NMR of the crude product shows it to consist of a mixture of four diastereoisomers, two of which are in higher proportion (41 and 48%). On the other hand, the addition of triphenyltin hydride to the same olefin (Scheme 1) leads to a mixture of only two diastereoisomers (31 and 69%). Similarly, hydrostannation of (–)-menthyl(*E*)-2-phenyl-2-butenolate (**2**)

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Scheme 1. Addition of triorganotin hydrides to (–)-menthyl(*E*)-2,3-diphenylpropenoate (1) and (–)-menthyl(*E*)-2-phenyl-2-butenate (2).

(Scheme 1) with trimethyltin hydride gives a mixture of four diastereoisomers (according to the ¹¹⁹Sn-NMR spectrum: 43.4, 43.4, 5.6 and 7.6%).

The ¹¹⁹Sn-NMR analysis of the crude products obtained in the addition of tri-*n*-butyltin- and triphenyltin hydrides to the ester 2 also shows these products to consist of mixtures of four tributyltin adducts (40.3, 40.3, 11.3 and 8.1%) and only two triphenyltin adducts (76 and 24%), respectively.

Although separation of all these diastereomers by column chromatography (silica gel 60) is not entirely feasible, this method enabled us to separate the stereoisomers obtained in higher yield (3, 4, 8 and 9, Scheme 1) from those obtained in lower yield (mixtures 5 + 5' and 10 + 10'), and also the diastereoisomers 6 and 7. The main ¹H-, ¹³C- and ¹¹⁹Sn-NMR characteristics of the compounds are summarized in Tables 1 and 2.

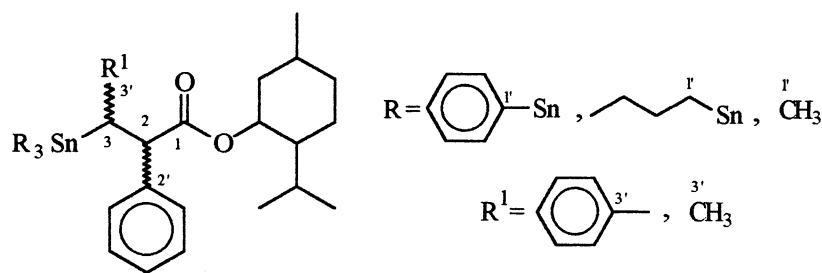
The ¹³C-NMR chemical shifts (Table 1) were assigned through the analysis of the multiplicity of the signals by means of DEPT experiments and taking into account the magnitude of ⁿJ(¹³C, ¹¹⁹Sn) coupling constants. The use of the Karplus-type relationship existing [4] between the value of the ³J(¹³C, ¹¹⁹Sn) coupling constants and the dihedral angle, together with ¹H-NMR data (Table 2), enabled us to deduce the stereochemistry of the adducts. Thus, the ³J(Sn, C=O) coupling constant with values ranging from 11.7 to 16.2 Hz for adducts 3 and 6–9, and not observed in compound 4 (Table 1, C-1) correspond ([4]b) to dihedral

angles close to 60°. Similarly, the values of ³J(Sn–C–C–Ph) coupling constants for compounds 3, 4 and 6–9 within the range 35.0–52.9 Hz (Table 1, C-2') indicate a dihedral angle of about 180° between the trialkylstannyl moiety and the phenyl group attached to C-2.

The ¹H-NMR spectra (Table 2) of compounds 3, 4 and 6–9 show that the ³J(H, H) coupling constants for the protons attached to C-2 and C-3 lie between 8.2 and 12.5 Hz, indicating that these protons are antiperiplanar. The ³J(Sn–C–C–H) coupling constants for compounds 3, 4 and 6–9 with values ranging from 25.2 to 52.0 Hz suggest a dihedral angle close to 60°. Taking into account all these values, it is possible to attribute a *threo* configuration (Fig. 1, I) to all these diastereoisomers, i.e. (2*R*, 3*R*)- and (2*S*, 3*S*)- for compounds 3, 4, 6 and 7, and (2*R*, 3*S*)- and (2*S*, 3*R*) for compounds 8 and 9.

On the other hand, the ¹³C-NMR spectra (Table 1) show that the values of the ³J(Sn, C=O) coupling constants for compounds 5, 5', 10 and 10' lie between 66.1 and 81.7 Hz, indicating a dihedral angle of about 180°. The small values of ³J(Sn–C–C–Ph) coupling constants for these compounds—not observed (5 and 5'), 15.2 (10) and 13.6 Hz (10')—suggest a dihedral angle close to 60° between the trialkylstannyl group and the phenyl group attached to C-2. The ¹H-NMR spectra (Table 2) of compounds 5, 5', 10 and 10' show that the ³J(H, H) coupling constants for the protons attached to C-2 and C-3 are within the range 12.2–13.5 Hz, indicating a dihedral angle of 180° between these

Table 1
 ^{13}C - and ^{119}Sn -NMR data of compounds **3**–**10** + **10'**^a



Compound	R	R ¹	C(1)	C(2)	C(3)	C(1')	C(2')	C(3')	Other signals	¹¹⁹ Sn
3	<i>n</i> -Bu	Ph	173.95 (14.6)	54.74 (n.o.)	37.34 (261.9)	10.27 (314.1)	140.08 (43.2)	144.30 (26.7)	^c	— 9.0
4	<i>n</i> -Bu	Ph	174.26 (n.o.)	54.92 (n.o.)	37.48 (261.9)	10.53 (314.1)	140.40 (48.3)	144.25 (26.7)	^d	— 6.7
5 ^b	<i>n</i> -Bu	Ph	174.30 (66.1)	55.14 (n.o.)	39.08 (n.o.)	9.28 (311.5)	138.97 (n.o.)	144.58 (25.4)	^e	— 12.0
5' ^b	<i>n</i> -Bu	Ph	174.30 (66.1)	55.54 (n.o.)	39.45 (n.o.)	9.35 (n.o.)	138.97 (n.o.)	144.43 (n.o.)	^f	— 12.7
6	Ph	Ph	174.00 (11.7)	54.90 (13.5)	40.70 (358.4)	139.30 (491.2)	141.90 (35.0)	139.30 (26.0)	^g	— 113.5
7	Ph	Ph	174.60 (16.2)	55.20 (15.2)	40.80 (368.8)	139.60 (489.3)	142.90 (35.9)	139.95 (24.2)	^h	— 124.4
8	Me	Me	174.24 (13.4)	56.88 (10.8)	23.46 (394.4)	—9.79 (319.5)	140.08 (44.0)	16.42 (12.5)	ⁱ	7.2
9	Me	Me	174.22 (12.6)	57.09 (9.0)	22.44 (391.3)	—9.99 (318.6)	140.18 (52.9)	15.97 (10.0)	^j	10.3
10 ^k	Me	Me	174.66 (81.7)	58.23 (n.o.)	22.32 (398.2)	—10.46 (314.2)	140.16 (15.2)	16.29 (n.o.)	^l	11.3
10' ^k	Me	Me	174.58 (80.8)	58.21 (n.o.)	21.99 (394.9)	—10.74 (312.7)	139.95 (13.6)	16.17 (n.o.)	^m	7.9

^aIn CDCl₃; chemical shifts, δ , in ppm with respect to TMS (^{13}C spectra) and Me₄Sn (^{119}Sn spectra); ⁿ*J*(Sn, C) coupling constants in Hz (in brackets); n.o. = not observed.

^bFrom mixtures (**5** + **5'**) with either **5** or **5'** in excess.

^c13.66; 16.08; 20.94; 21.90; 23.06; 25.78; 27.47 (58.5 Hz); 29.05 (17.8 Hz); 31.25; 34.18; 39.34; 74.79; 123.50; 126.41; 127.27; 127.91; 127.98.

^d13.93; 15.81; 20.33; 22.32; 23.27; 25.34; 27.78 (57.22 Hz); 29.32 (19.1 Hz); 31.72; 34.58; 41.44; 47.73; 74.87; 123.30; 126.42; 127.15; 127.20; 127.83; 127.91; 127.96.

^e13.47; 15.58; 20.65; 21.80; 23.09; 25.31; 27.25 (58.5 Hz); 28.75 (19.1 Hz); 31.18; 34.21; 40.33; 47.03; 74.04; 123.97; 126.53; 127.59; 127.95; 128.39; 128.79.

^f13.47; 15.45; 20.81; 25.31; 27.25 (58.5 Hz); 22.87; 28.75 (19.1 Hz); 31.18; 34.21; 40.24; 46.83; 73.85; 124.17; 127.03; 127.79; 128.16; 128.46.

^g15.33; 20.33; 21.78; 22.53; 24.68; 30.98; 33.95; 39.61; 46.89; 74.82; 124.17; 126.44; 127.64; 127.76; 127.81; 127.96; 128.01; 128.20; 128.30; 128.43; 128.55; 128.90; 135.87; 136.90; 137.13; 137.36.

^h15.78; 20.75; 21.86; 22.98; 25.71; 31.11; 33.97; 39.63; 41.76; 46.46; 75.10; 124.48; 126.49; 128.23; 127.89; 128.01; 128.23; 128.56; 137.31; 139.36.

ⁱ16.05; 20.72; 21.83; 23.03; 25.79; 31.15; 34.07; 39.91; 46.60; 74.41; 126.61; 127.77; 128.20.

^j15.48; 20.41; 21.95; 22.83; 24.98; 31.24; 34.11; 40.75; 47.14; 74.23; 126.67; 127.86; 128.18.

^k From mixtures (**10** + **10'**) with either **10** or **10'** in excess.

^l17.42; 20.87; 21.86; 22.32; 23.60; 26.18; 31.69; 34.60; 40.81; 47.26; 74.85; 127.74; 128.60; 128.71.

^m15.32; 20.60; 21.10; 22.26; 23.40; 26.07; 31.63; 34.55; 40.73; 46.91; 74.53; 127.15; 127.79; 128.02.

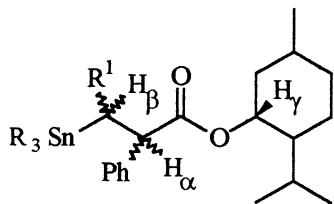
protons. These values strongly suggest that compounds **5**, **5'**, **10** and **10'** have the *erythro* configuration (Fig. 1, **II**), i.e. (2*S*, 3*R*)- and (2*R*, 3*S*)- for compounds **5** and **5'**, and (2*R*, 3*R*)- and (2*S*, 3*S*)- for compounds **10** and **10'**.

The absolute configuration of adducts **3**, **4** and **6**–**9** was established by chemical correlation according to Scheme 2.

Bromodestannylation of adducts **3**, **4** and **6**–**9**, in carbon tetrachloride and using a ratio adduct/bromine 1:2 in the case of trimethyl- and tri-*n*-butylstannyl adducts and a 1:4 ratio for the triphenylstannyl ad-

ducts, led to the mixtures of the corresponding β -bromo esters. In the case of adducts **3**, **4**, **6**, and **7**, the resulting β -bromo esters could be separated and were identified by comparison with authentic samples [3]. On the other hand, we were not able to separate the mixture of β -bromo esters resulting from the bromodestannylation of adducts **8** and **9**. Direct reduction of the mixtures of β -bromo esters (**11** + **11'**) with an excess of lithium aluminium hydride yielded (*R*)-(–)-2,3-diphenylpropan-1-ol (**13a**) [5] in the case of the bromoesters derived from adducts **3** and **6** and (*R*)-(–)-

Table 2

¹H-NMR data of compounds **3–10** + **10'**^a

Compound	R	R ¹	H _α ³ J(Sn, H)	H _β ² J(Sn, H)	³ J(H _α , H _β)	H _γ	Other signals
3	<i>n</i> -Bu	Ph	4.29 (35.4)	3.29 (57.7)	11.5	4.71 (m)	d
4	<i>n</i> -Bu	Ph	4.28 (28.8)	3.39 (57.1)	12.5	4.64 (m)	e
5^b	<i>n</i> -Bu	Ph	4.34 (n.o.)	3.42 (55.6)	13.5	4.43 (m)	f
5'^b	<i>n</i> -Bu	Ph	4.28 (n.o.)	3.39 (43.7)	13.4	4.45 (m)	g
6	Ph	Ph	4.42 (25.2)	3.93 (61.0)	11.8	4.32 (m)	h
7	Ph	Ph	4.44 (26.7)	3.73 (69.3)	8.2	4.30 (m)	i
8	Me	Me	3.61 (52.0)	1.87 (m)	9.8	4.65 (m)	j
9	Me	Me	3.46 (40.2)	1.93 (m)	11.0	4.48 (m)	k
10^c	Me	Me	3.48 (39.0)	2.09 (m)	12.2	4.63 (m)	l
10'^c	Me	Me	3.40 (n.o.)	1.96 (m)	12.9	4.66 (m)	m

^aIn CDCl₃; chemical shifts, δ , in ppm with respect to TMS; ⁿJ(Sn, H) coupling constants in Hz (in brackets); multiplicity: d = doublet, m = multiplet (in brackets), n.o. = not observed.

^bFrom mixtures (**5** + **5'**) with either **5** or **5'** in excess.

^cFrom mixtures (**10** + **10'**) with either **10** or **10'** in excess.

^d0.87 [d, 3H, ³J(H, H) 7.0 Hz]; 0.89 [d, 3H, ³J(H, H) 7.0 Hz]; 0.94 [d, 3H, ³J(H, H) 6.9 Hz]; 1.28 [d, 3H, ³J(H, H) 7.2 Hz]; 1.38–1.62 (m, 6H); 1.64–1.75 (m, 1H); 2.09–2.20 (m, 1H); 6.85–6.91 (m, 2H); 7.02–7.30 (m, 8H).

^e0.80 [d, 3H, ³J(H, H) 7.5 Hz]; 0.85 [d, 3H, ³J(H, H) 7.9 Hz]; 0.89 [d, 3H, ³J(H, H) 7.6 Hz]; 0.92 [d, 3H, ³J(H, H) 6.9 Hz]; 1.21–1.52 (m, 7H); 1.71 (m, 1H); 1.96 (m, 1H); 6.80–6.90 (m, 2H); 7.07–7.17 (m, 8H).

^f0.71 [d, 3H, ³J(H, H) 7.0 Hz]; 0.78 [d, 3H, ³J(H, H) 6.7 Hz]; 0.76 [d, 3H, ³J(H, H) 6.7 Hz]; 0.80 [d, 3H, ³J(H, H) 7.0 Hz]; 1.03–1.33 (m, 9H); 1.40–1.50 (m, 1H); 1.52–1.62 (m, 1H); 6.94–7.08 (m, 2H); 7.11–7.57 (m, 8H).

^gSignals superimposed with those belonging to isomer **5**.

^h0.26 [d, 3H, ³J(H, H) 7.5 Hz]; 0.45 [d, 3H, ³J(H, H) 7.5 Hz]; 0.77 [d, 3H, ³J(H, H) 7.4 Hz]; 0.94–1.10 (m, 7H); 1.24 (m, 1H); 1.52 (m, 1H); 6.83–6.95 (m, 2H); 7.00–7.09 (m, 8H); 7.24–7.47 (m, 15H).

ⁱ0.51 [d, 3H, ³J(H, H) 6.7 Hz]; 0.75 [d, 3H, ³J(H, H) 7.3 Hz]; 0.79 [d, 3H, ³J(H, H) 6.7 Hz]; 0.84–1.22 (m, 7H); 1.25 (m, 1H); 1.55 (m, 1H); 6.84–6.94 (m, 2H); 6.96–7.14 (m, 8H); 7.18–7.46 (m, 15H).

^j0.026 [s, ³J(Sn, H) 51.4 Hz]; 0.74 [d, 3H, ³J(H, H) 6.7 Hz]; 0.81 [d, 3H, ³J(H, H) 7.3 Hz]; 0.86 [d, 3H, ³J(H, H) 6.7 Hz]; 1.00 [d, 3H, ³J(H, H) 7.3 Hz, ³J(Sn, H) 65.0 Hz]; 1.41 (m, 1H); 1.05–1.36 (m, 7H); 7.20–7.31 (m, 5H).

^k0.006 [s, ³J(Sn, H) 51.2 Hz]; 0.29 [d, 3H, ³J(H, H) 6.7 Hz]; 0.48 [d, 3H, ³J(H, H) 6.7 Hz]; 0.83 [d, 3H, ³J(H, H) 6.7 Hz]; 0.89 [d, 3H, ³J(H, H) 7.3 Hz]; 1.38 (m, 1H); 1.80 (m, 1H); 1.05–1.27 (m, 7H); 7.06–7.24 (m, 5H).

^l–0.26 [s, ³J(Sn, H) 50.0 Hz]; 0.45 [d, 3H, ³J(H, H) 6.7 Hz]; 0.77 [d, 3H, ³J(H, H) 6.8 Hz]; 0.81 [d, 3H, ³J(H, H) 6.7 Hz]; 1.17–1.35 (m); 1.44 (m); 1.79 (m); 7.10–7.37 (m).

^m–0.06 [s, ³J(Sn, H) 52.4 Hz], signals of **10** and **10'** superimposed.

2-phenylbutan-1-ol (**13b**) [6] in the case of the bromoesters obtained from adduct **8**. Similarly, reduction of mixtures (**12** + **12'**) led to (*S*)-(+)-2,3-diphenylpropan-1-ol (**14a**) [5] in the case of the bromoesters derived from adducts **4** and **7**, and to (*S*)-(+)-2-phenylbutan-1-ol (**14b**) [6] in the case of the bromoesters obtained from adduct **9**.

Working back from the stereochemistry of the propanols obtained (**13a**, **13b**, **14a** and **14b**) it is possible to make the stereochemical assignments for the starting adducts. Thus, the absolute configuration of adducts **3** and **6** is (2*R*, 3*R*), of adduct **8** is (2*R*, 3*S*), of adducts **4** and **7** is (2*S*, 3*S*), and **9** is (2*S*, 3*R*).

These results and those reported previously [1,3] (Table 3) clearly indicate that the hydrostannation of

acyclic activated olefinic systems takes place with a high degree of stereoselectivity. The fact that this stereoselectivity is almost the same whether the starting olefin contains a methyl or a (–)-menthyl ester group, indicates that in these additions, the observed stereoselectivity is independent of the size of the ester group.

The observed *threo* stereochemistry of the main or only products obtained in the hydrostannation of alkyl(*E*)-2-phenyl-3-methyl (phenyl) propenoates indicates that these additions take place following a preferential *syn* steric course. This preferential stereochemistry could be explained [2], taking into account the fact that acyclic radicals can react with high stereoselectivity if they adopt preferred conformations. The six possible intermediate alkyl radicals resulting

from the addition of the tin radicals to the olefins **1** and **2** are shown in Fig. 2. Fig. 2 also shows the expected products according to the side of the hydrogen transfer by another molecule of tin hydride in the last step of the radical chain.

Most of the examples of 1,2-induction follow an A-strain model [2,7], where a conjugating substituent on the radical-bearing carbon dictates that the smallest substituent on the adjacent stereocenter points to the same direction as the conjugating group. Considering that this energetically favored arrangement is not present in the conformations **C** and **F** (Fig. 2), and also that the tin hydride would be approaching the radicals **C** and **F** between the two largest groups in order to effect the hydrogen transfer, we can consider these radicals as intermediates in high-energy pathways that could be discarded.

Although there are many examples ([7]a) of reactions in which the conjugating substituents attached to the radical carbon are either phenyl groups (benzylic systems) or ester groups (heteroallylic systems), we have not found any reference about radical systems in which both conjugating groups, phenyl and ester, are attached to the radical center. The α -phenyl- β -trialkylstannyl radicals depicted in Fig. 2 belong to the latter class of radical systems, i.e. they have two conjugating groups attached to the radical carbon.

Considering that these additions lead to major or only products originated in a *syn* pathway, the radicals **A** and **B** will be first considered. Both radicals contain the hydrogen attached to carbon β on the same side of a conjugating group: the ester group in radical **A** and the phenyl group in radical **B**. Then, on the basis of steric effects, namely the hydrogen transfer between the medium or the larger group and the C-3 hydrogen, and A-strain effects—A[1,2]-strain for radical **A** and A[1,3]-strain for radical **B**—radical **B** appears to be disfavored relative to radical **A** in the second step of the propagation chain. However, in radical **B**, the trialkylstannyl group occupies an eclipsed position relative to the half-filled carbon p orbital which, according to Kochi et al. [8] is the preferred conformation for these stannyl

radicals due to stabilization by hyper- and homoconjugative effects. Moreover, in favor of radical **B** is the fact that the phenyl group is a better conjugating group than the ester group [9].

On the other hand, in radical **E**, the conjugating phenyl group points to the same direction as the hydrogen atom attached to C-3, but there is no eclipsing of the trialkylstannyl group with the radical orbital, and although in radical **D**, this eclipsing exists, the conjugating group is, in this case, the ester group.

Taking into account the previous discussion, we strongly believe that the observed stereoselectivity is due to the fact that the intermediate radical will adopt preferentially configuration **B** and, therefore, that the hydrogen transfer will take place *anti* with respect to the trialkylstannyl group and not to the larger R^1 (methyl or phenyl) substituent. The difference of diastereoselectivity observed between the hydrostannations carried out with triphenyltin hydride (d.e. 100%) and with trimethyl- and tri-*n*-butyltin hydrides (d.e. ca. 75%) could be ascribed both to the higher reactivity of the triphenyltin hydride (better donor) and to its bulkiness that would make interconversion of **B** to **D** slower.

This conclusion is also supported by previous studies on the hydrostannation of methyl(*E*)-2-methyl-3-phenylpropenoate and methyl(*E*)-2-methyl-2-butenolate (methyl tiglate) with trimethyl-, tri-*n*-butyl-, and triphenyltin hydride [1]. These studies showed that the configuration of the main or only products ([4]b) was the *erythro*, i.e. the opposite of that of the products obtained in the hydrostannation of olefins **1** and **2**, and of their methyl ester analogs. The analysis of the intermediate radicals can help again to justify the observed stereochemistry. Replacing in Fig. 2 the phenyl group attached to the carbon radical by a methyl group will show the intermediate α -methyl- β -trialkylstannyl radicals corresponding to these additions.

The reversal of the stereochemistry could be then explained, considering that, in this case, the only intermediate radical in which the two stabilizing effects, namely the trialkylstannyl group eclipsed with the half-filled carbon p orbital and the conjugating group on the same side as the smaller group (hydrogen) in the neighboring stereocenter, are present, is **G** (Fig. 3).

The discussed results strongly suggest that in the case of the hydrostannation of acyclic activated olefinic systems, the observed stereoselectivity is related to the existence of preferred conformations in the intermediate radicals arising from both A-strain effects and the hyperconjugative interaction existing between the β -trialkylstannyl substituent and the half-filled carbon p orbital. Our results are in agreement with those recently reported by Giese et al. [10], in that the degree and the direction of the 1,2-induction is decided by the substituents at the radical center. But we feel that this factor alone is not enough to explain the observed

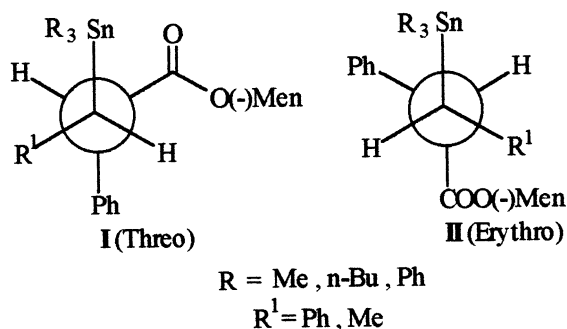
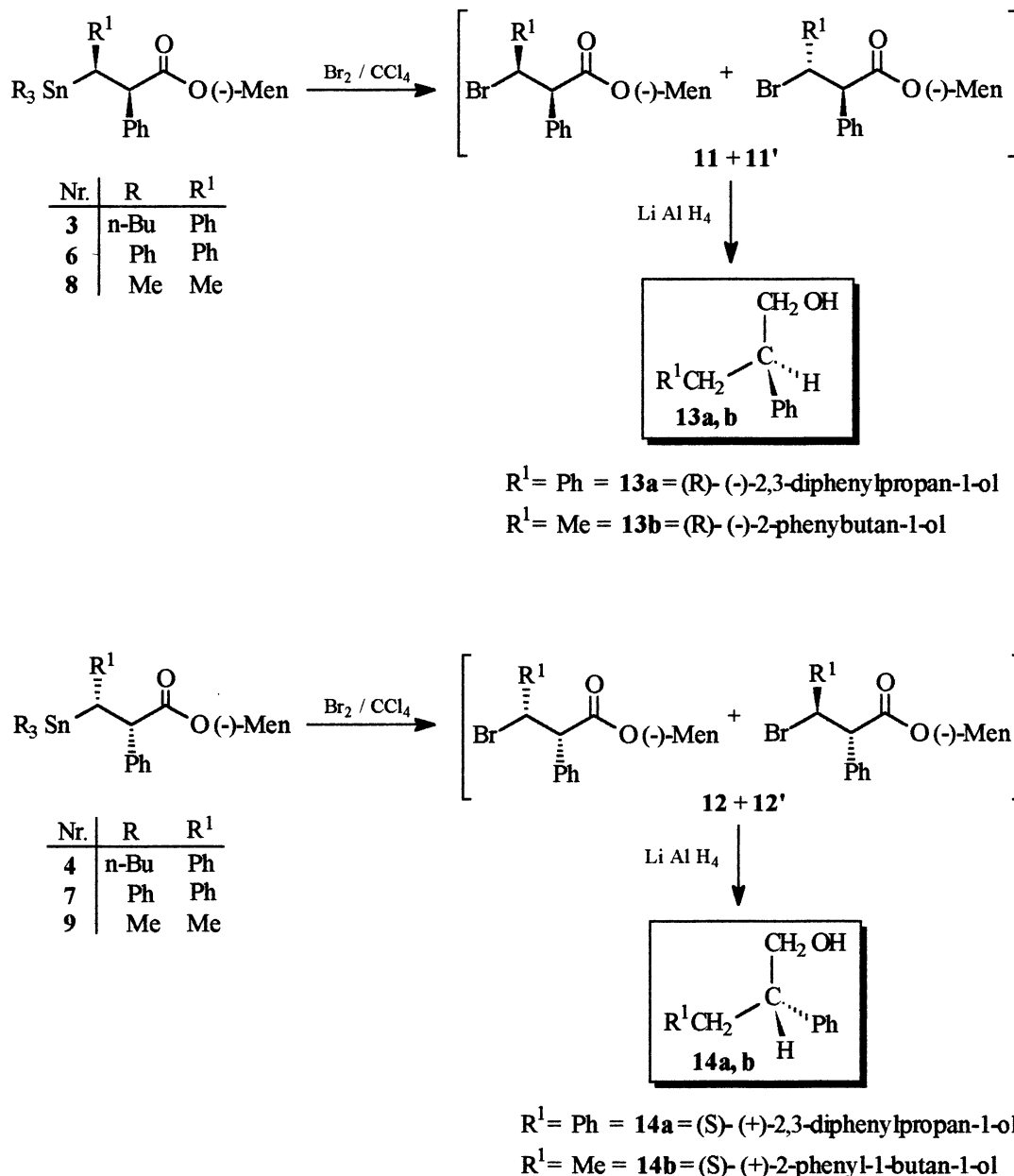


Fig. 1. Preferred conformations of *threo* and *erythro* compounds **3–10'** (only one stereoisomer of each is shown).



Scheme 2. Reaction sequences for obtaining the absolute configuration of adducts 3, 4 and 6–9.

reversal of the stereochemistry in the particular case of the hydrostannation of acyclic activated olefinic systems.

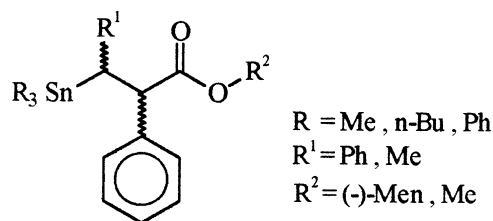
Further work in order to obtain more information on the stereochemistry of hydrostannations is in progress.

3. Experimental

The NMR spectra were determined partly at Dortmund University (Germany) (^1H , ^{13}C and ^{119}Sn) and at Alicante University (Spain) (^1H and ^{13}C), using a Bruker AM 300 instrument, and partly at IQUIOS (Rosario,

Argentina) with a Bruker AC 200 instrument (^1H and ^{13}C). IR spectra were recorded with a Perkin-Elmer 599B spectrophotometer. Microanalyses were performed at Dortmund University and at INQUIMAE (University of Buenos Aires, Argentina). Specific rotations were measured with a Polar L- μP , IBZ Messtechnik. All the solvents and reagents used were analytical reagent grade. Triorganotin hydrides were prepared by reduction of the corresponding chlorides with lithium aluminium hydride and the starting olefins, **1** and **2**, were prepared as described [3]. Caution: due to its very high toxicity, trimethyltin hydride must always be handled in a very efficient fume cupboard.

Table 3
Organotin hydride additions to (*E*)-2,3-disubstituted alkyl propenoates



Hydride	Configuration	$R^2 = (-)\text{-Menthyl}$		$R^2 = \text{Methyl}^b$	
		$R^1 = \text{Ph}$	$R^1 = \text{Me}$	$R^1 = \text{Ph}$	$R^1 = \text{Me}$
Me_3SnH	<i>Threo</i>	89	87	80	75
	<i>Erythro</i>	11	13	20	25
$n\text{-Bu}_3\text{SnH}$	<i>Threo</i>	89	85 ^a	85	100
	<i>Erythro</i>	11	15 ^a	15	—
Ph_3SnH	<i>Threo</i>	100	100 ^a	100	100
	<i>Erythro</i>	—	—	—	—

^aFrom the ^{119}Sn -NMR spectra.

^bSee [1,3].

All the reactions were carried out following the same procedure. One experiment is described in detail in each case in order to illustrate the method used.

3.1. Addition of organotin hydrides to

(*-*)-menthyl(*E*)-2,3-diphenylpropenoate (**1**) and (*-*)-menthyl(*E*)-2-phenyl-2-butenolate (**2**). Reaction of (*-*)-menthyl(*E*)-2,3-diphenylpropenoate (**1**) with tri-*n*-butyltin hydride. Synthesis of (*-*)-menthyl(2*R*, 3*R*)-, (2*S*, 3*S*)-, and (2*RS*, 3*SR*)-2,3-diphenyl-3-(triphenyl-stannyl) propenoates (**3**, **4**, **5**, and **5'**)

The ^1H , ^{13}C and ^{119}Sn -NMR data of the new organotin compounds are included in Tables 1 and 2; other physical characteristics, reaction conditions, and elemental analyses (C, H) are given in Table 4.

Ester **1** (10 g, 0.0276 mol) was treated for 6 h with tri-*n*-butyltin hydride (12.03 g, 0.0414 mol) under nitrogen at 85 °C and with azobisisobutyronitrile

(AIBN) as a catalyst (this optimal time of reaction and the use of an adequate excess of organotin hydride were indicated by earlier experiments in which the reaction was monitored by taking samples at intervals and observing the disappearance of the Sn–H absorption by IR, and by checking at the end of the reaction that the ^1H -NMR spectrum of the reaction mixture no longer showed the presence of unchanged olefin). The ^1H -NMR spectrum showed that under these conditions, a quantitative yield (based on starting olefin) of a mixture of diastereoisomeric adducts **3**, **4** and **5** + **5'** was obtained. The relative amount of each diastereoisomer in the mixture was 41.5 (**3**), 47.8 (**4**), 5.1 (**5**), and 5.5% (**5'**) as shown by the integration of the ^{119}Sn -NMR spectrum.

Column chromatography on silica gel 60 of the crude mixture, yielded 13.2 g of a mixture of compounds **3** and **4**, which were eluted with light petroleum (b.p. 30–65°C) and light petroleum (b.p. 30–65°C)/carbon

Table 4

Some physical properties, reaction conditions and elemental analyses

Compound no.	IR ^a $\nu(\text{C}=\text{O})$	M.p. (°C) ^b or μ_D^{20}	$[\alpha]_D^{25}$ (concentration) ^c	Time ^d (85°C)	Elemental analyses: found (calc.) (%)	
					C	H
3	1725 ^e	1.5290	−25.0° (1.70)	360	68.22 (67.99)	8.75 (8.94)
4	1729 ^e	1.5250	−8.0° (1.26)	360	67.73 (67.99)	9.22 (8.94)
6	1713	174–175	−49.0° (8.80)	240	72.17 (72.38)	6.58 (6.49)
7	1720	95–96	−15.0° (1.80)	240	72.59 (72.38)	6.23 (6.49)
8	1725	99–100	−24.0° (0.70) ^f	120	59.62 (59.37)	8.31 (8.23)
9	1730	44–45	+26.0° (0.84) ^f	120	59.51 (59.37)	8.35 (8.23)

^aIR spectra as KBr pressed disc except when otherwise stated; ν in cm^{-1} . ^bRecrystallized from ethanol. ^cIn benzene except when otherwise stated.

^dIn min; hydride/olefin ratio: 1.5. ^eFilm. ^fEthyl ether.

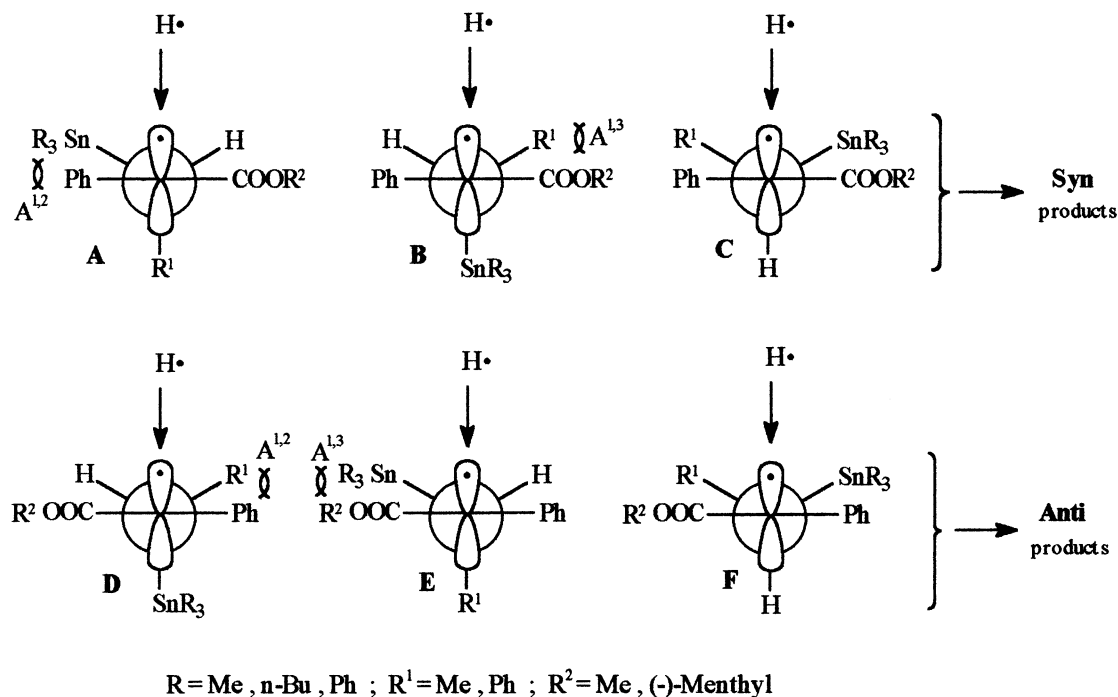


Fig. 2. Intermediate α -phenyl- β -trialkylstannyl radicals (only one enantiomer of each is shown).

tetrachloride 1:1, and 1.54 g of a mixture of compounds **5** and **5'**, which eluted in the last fractions of the chromatography. Compounds **3** and **4** were obtained pure from the chromatography of the mixture **3** + **4**, using a fraction collector [eluent: light petroleum (b.p. 30–65°C)/carbon tetrachloride 1:1]. The mixture of compounds **5** + **5'** could not be separated by this method, but we were able to obtain mixtures enriched in each diastereoisomer which enabled to obtain the NMR characteristics of each diastereoisomer.

The crude products obtained in the hydrostannylation of ester **1** with triphenyltin hydride and of ester **2** with trimethyltin hydride (see experimental conditions in Table 4), were purified by column chromatography and the adducts separated by fractional recrystallization (ethanol).

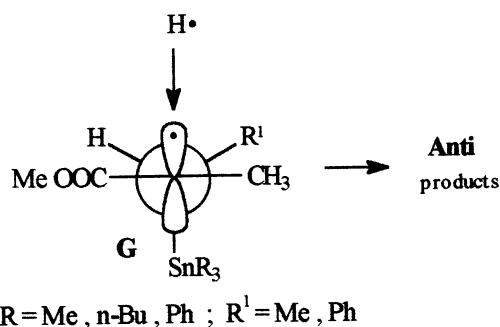


Fig. 3. Preferred intermediate α -methyl- β -trialkylstannyl radical.

3.2. Bromodestannylation reactions. Reaction of (–)-menthyl(2*R*, 3*S*)-2-phenyl-3-(trimethylstannyl)-butanoate (8**) with bromine. Synthesis of the mixture of (–)-menthyl(2*R*, 3*S*)- and (2*R*, 3*R*)-2-phenyl-3-bromobutanoates (in Scheme 2: **11** + **11'** with $R = \text{Me}$) with LiAlH_4 . Synthesis of (R)-(–)-2-phenylbutan-1-ol (**13b**)**

To a solution of **8** (1 g, 0.0022 mol) in carbon tetrachloride (6 ml) was added dropwise a solution of bromine in carbon tetrachloride (5.4 ml of a 0.8 M solution, 0.0044 mol), with stirring, in the dark. After 4 h, the ^1H -NMR showed a quantitative yield of a mixture of (–)-menthyl(2*R*, 3*S*)- and (2*R*, 3*R*)-2-phenyl-3-bromobutanoates (**11** + **11'**, $R = \text{Me}$). The solvent was distilled off under reduced pressure. The crude product purified by column chromatography (silica gel 60), yielded 0.75 g, (89.3%) of the mixture of compounds **11** + **11'** ($R = \text{Me}$), eluted with carbon tetrachloride.

3.3. Reduction of the β -bromo esters. Reaction of the mixture of (–)-menthyl(2*R*, 3*S*)- and (2*R*, 3*R*)-2-phenyl-3-bromobutanoates (in Scheme 2: **11 + **11'**, $R = \text{Me}$) with LiAlH_4 . Synthesis of (R)-(–)-2-phenylbutan-1-ol (**13b**)**

To a suspension LiAlH_4 (0.47 g, 0.0124 mol) in anhydrous ether (5 ml) was added with stirring a solu-

tion of **11** + **11'** (R = Me) (1.20 g, 0.0031 mol) in ether (60 ml). The mixture was heated under reflux for 6 h. After cooling, the mixture was decomposed by the addition of HCl (20%, 6 ml). The organic layer was dried with MgSO₄ and the solvent was distilled off under reduced pressure. The elimination of the (–)-menthol generated in the reaction under reduced pressure with the aid of a cold finger led to alcohol **13b** (0.43 g, 90%), [α]_D²⁰ –24.5° (c, 0.71; ether) ([6] [α]_D²⁰ –19.45° (neat)).

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