1,2-Asymmetric Induction in Radical-mediated Allylation of Diethyl (2*S*,3*S*)-3-Bromo-2-oxysuccinates: Efficient Stereoselectivity Enhancement by Complexation with Eu(fod)$_3$

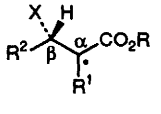
Hajime Nagano* and **Yukie Kuno**

Department of Chemistry, Faculty of Science, Ochanomizu University, Otsuka, Bunkyo-ku, Tokyo 112, Japan

Allylation of diethyl (2*S*, 3*S*)-3-bromo-2-trimethylsilyloxysuccinate with allyltributyltin in the presence of Eu(fod)$_3$ was found to give diethyl (2*R*, 3*R*)-3-allyl-2-trimethylsilyloxysuccinate with high diastereoselectivity [(2*R*, 3*R*): (2*R*, 3*S*) = 8.6 : 1].

A current interest in radical chemistry is the control of acyclic stereochemistry. In particular, attention has focused on chirality transfer using stereogenic centres adjacent to the radical carbon atom (1,2-asymmetric induction),[1] and recently stereoselective trapping of radicals **1** bearing a carbonyl group and a stereogenic centre has been demonstrated by Hart,[2] Guindon,[3,4f] Giese,[4] Curran,[5] and others.[6] However, little is known about controlling the stereochemistry by complexation of radical intermediates (whether cyclic or acyclic) with Lewis acids.[2c,3c,7] We now report that the stereoselectivity in the radical-mediated allylation of diethyl (2*S*, 3*S*)-3-bromo-2-oxysuccinates **2** yielding diethyl 3-allyl-2-oxysuccinates **3** (2*R*, 3*R*) and **4** (2*R*, 3*S*) was significantly affected when the reaction was conducted in the presence of Eu(fod)$_3$ [= tris(6,6,7,7,8,8,8-heptafluoro-2,2-dimethyloctane-3,5-dionato)europium].†

A summary of the allylation results is given in Table 1. Allylation of **2a–e** showed modest to poor stereoselectivities in the absence of Lewis acid (entries 1, 3, 5 and 8). Addition of 1.1 mol. equiv. of Eu(fod)$_3$ reversed the stereoselectivity in the reaction of **2a**, but the stereoselectivity enhancement induced by complexation was not large (entry 2). In the case of **2b**, **2c** and **2d** the addition of Eu(fod)$_3$ (1.1 mol. equiv.) led to high stereoselectivity enhancement (entries 4, 7 and 11).‡ The stereoselectivity in the reaction of **2c** and **2d** decreased as the molar ratio of Eu(fod)$_3$ was decreased (entries 6, 9 and 10), but further improvement of stereoselectivity was not attained even in the presence of 2 mol. equiv. of Eu(fod)$_3$. Allylation of **2e** and **2f** showed poor stereoselectivity in the presence of Eu(fod)$_3$ (entries 12 and 13).§



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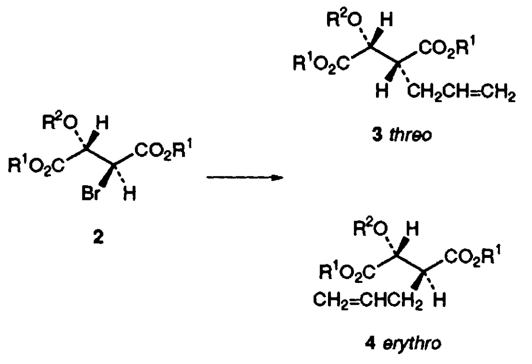

2

3 *threo*

4 *erythro*

a; R^1 = Et, R^2 = H
b; R^1 = Et, R^2 = Ac
c; R^1 = Et, R^2 = SiMe$_3$
d; R^1 = Et, R^2 = SiMe$_2$Bu^t
e; R^1 = Et, R^2 = SiPh$_2$Bu^t
f; R^1 = Pr^i, R^2 = SiMe$_2$Bu^t

Scheme 1 *Reagents and conditions*: CH$_2$=CHCH$_2$SnBu$^n_3$, AIBN, Lewis acid, CH$_2$Cl$_2$, *hν*

Table 1 Stereoselectivity in allylation of **2a–f**[a]

Entry	Bromide **2**[b]	Eu(fod)$_3$/ mol. equiv.	Yield (%)	Diasteroisomer ratio[b,c] **3**:**4**
1	**a**	—	85	1 : 1.9[d]
2	**a**	1.1	63	1.7 : 1[d]
3	**b**	—	91	1.9 : 1
4	**b**	1.1	72	3.4 : 1
5	**c**	—	63	1.3 : 1
6	**c**	0.1	45	3.0 : 1[e]
7	**c**	1.1	62	8.6 : 1[e]
8	**d**	—	57	1.1 : 1
9	**d**	0.1	81	2.7 : 1
10	**d**	0.3	69	4.1 : 1
11	**d**	1.1	67	5.7 : 1
12	**e**	1.1	66	1.5 : 1
13	**f**	1.1	77	1.7 : 1

[a] Allylation of **2** was conducted with 2 mol. equiv. of allyltributyltin and a catalytic amount of AIBN in CH$_2$Cl$_2$ (0.07 mol dm^{-3}) under irradiation with 100 W sunlamp for *ca.* 24 h in the presence (or absence) of Eu(fod)$_3$. After treatment with KF the mixture was passed through a short column of neutral alumina to eliminate Eu(fod)$_3$ (entries 9–11), or purified by silica gel flash chromatography (entries 1–5, 8, 12, and 13). [b] Precursors **2** and authentic products **3** and **4** were prepared from diethyl (2*R*, 3*R*)-tartrate (ref. 9) and diethyl malate (ref. 8), respectively. [c] Product ratios of the inseparable mixtures were determined by ^{1}H NMR integration of 2-H. [d] The ratio of **3a** and **4a** was determined after acetylation. [e] The mixture of **3c** and **4c** was desilylated, and then acetylated to obtain the yield (for three steps) and the diastereoisomer ratio.

In conclusion we have demonstrated that the radical-based allylation of **2c** with allyltributyltin in the presence of Eu(fod)$_3$ gives the *threo*-isomer **3c** with high stereoselectivity. Chelation-controlled allylation of the dianion derived from diethyl malate gives *erythro*-**4a** with extremely high stereoselectivity,[8] and alkylation of diethyl 2,3-epoxysuccinate derived from optically active diethyl tartrate gives diethyl *erythro*-3-alkyl-2-hydroxysuccinate.[9] This work and ours are complementary.

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Footnotes

† The diastereoisomer ratio **3d** : **4d** in the allylation of **2d** decreased in the order of Pr(fod)$_3$ (6.3 : 1)>Eu(fod)$_3$ (5.7 : 1)>Gd(fod)$_3$ (4.2 : 1)>Dy(fod)$_3$ (3.4 : 1)>Ho(fod)$_3$ (2.1 : 1)>Er(fod)$_3$ (2.2 : 1). Eu(tfc)$_3$ {=tris[3-(trifluoromethylhydroxymethylene)-(+)-camphorato]europium} was less effective. Pr(thd)$_3$ [=tris(2,2,6,6-tetramethylheptane-3,5-dionato)praseodymium] and Yb(thd)$_3$ had no effect on the diastereocontrol.

‡ Racemization was not observed after HPLC analysis of the (*R*)- and (*S*)-MTPA esters [**3** and **4**: R^1 = Et, R^2 = C(=O)C(OMe)CF$_3$Ph] derived from **3d** and **4d**.

§ The diastereoisomer ratio in the allylation of ethyl 2-bromo-3-(*tert*-butyldimethyl)silyloxybutanoate in the presence of 1.1 mol. equiv. of

$Eu(fod)_3$ was *anti*:*syn* = 4.2:1, whereas the ratio was 1.7:1 in the absence of the complex.[5c]

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